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THE
WONDERS
OF THE
MICROSCOPE;
OR,
AN EXPLANATION
OF THE
WISDOM OF THE CREATOR
IN OBJECTS COMPARATIVELY MINUTE,
ADAPTED TO THE
UNDERSTANDING OF YOUNG PERSONS.

Illustrated with Five large Copper-plates.

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INTRODUCTION.

THE microscope, the wonders of which will be displayed in the progress of this little volume, is an instrument enabling us to examine the structure of plants and animals; it extends the boundaries of the organs of vision with respect to all minute objects; it presents to the eye a multitude of beings, of whose existence we could form no idea without the assistance of glasses; it opens to the young and to the curious an inexhaustible source of information and pleasure. In a word, this pleasing instrument leads to the discovery of a thousand wonders in the works of His hand, who created ourselves, as well as the objects of our admiration; it improves the faculties, exalts the comprehension, and multiplies the means of happiness, and should, therefore, be rendered the means of exciting in our breasts emotions of gratitude to that

great

great and good Being to whom we are indebted for life, and all its various sources of enjoyment.

As the eye is the grand organ through which is derived all the pleasures arising from the microscope and other optical instruments, it will be right to give some account of the structure of this valuable organ, and of the nature of vision.

The disposition of the eyes is admirable. They are placed in the highest part of the body to command distant prospects; and, at a certain depth, surrounded with hard solid bones, that they may not be liable to injury. They move easily in the socket in all directions; they are wiped, and protected by the lids that keep perpetually opening and shutting. The eye lashes save them from too strong a light, and are safe guards in a thousand instances.

The interior structure of the eye is still more curious. The whole is composed of *coats*, of *humours*, and *muscles*. The outside coat or membrane is called the *cornea;* it is perfectly transparent to admit the rays of light, and hard as horn to resist the small blows and shocks to which it is liable. Behind the cornea is another membrane called the *uvea*, which is circular and coloured. In the middle of this there is an opening which is called the *pupil*; it appears black, and becomes greater or less according to the degree of light to which it is exposed. Behind the uvea are three other substances behind one another; the first is the *aqueous*, or watery humour; the second is a *chrystalline* kind of substance; and the third is called the *vitreous* humour, because, in appearance, it resembles melted glass. Beyond these is a substance called the *retina*, or network, on which the images of all objects whatever that we see are painted; and connected with the retina is the *optic nerve*, which communicates with the brain, and gives the mind the sense of sight.

The structure of the eye is not more wonderful, than the nature of vision is astonishing. No object can become visible to us unless rays of light proceed from it and fall upon our eyes. These rays, which minister the sense of sight, are, perhaps, the most wonderful part of inanimate creation, both on account of their extreme minuteness, and the inconceivable velocity with which they travel from the sun, viz. at the rate of half a million of miles in a minute.

A consideration also which may justly excite our wonder is that the largest objects are painted in our eyes extremely small, and yet we see every thing according to its real size. How is it that we see at one and the same instant, a multitude of houses, churches, and other large buildings, so completely distinct, since they are all painted on the small space contained on the retina of the eye?

Another curious circumstance is, that having two eyes, on both of which the same picture is painted, yet we do not see double; in looking upon the sun or moon, though the image is distinctly formed on each eye, yet we see but one sun or one moon, and so of all other objects. The habit of seeing, from our earliest infancy, leads us to overlook the difficulties in the operation, and to suppose it a thing extremely simple and easy to comprehend. Nevertheless the wisest philosopher has never yet been able satisfactorily to explain the manner in which we see objects.

But though there is much for which the

wisest among us cannot account on this subject, yet we can explain the mechanical mode of vision by a very easy experiment. Darken a room as completely as possible, and then let the light be admitted by a small hole; if the weather be very clear, you will see on the wall of the room, a picture of all those external objects which are opposite to the hole. The image of the objects that are stationary, as trees, houses, &c. will appear fixed; while the images of those that are in motion will be seen to move. Now the same thing that takes place on the wall, happens with regard to the eye, the images are painted upon it: of those that are stationary, the picture is at rest; but with regard to moving ones, the picture moves on the eye as it does on the wall. You will observe that the image of every object painted on the wall is inverted, because the rays cross one another at their entrance at the small hole, and people will appear to be walking on their heads, and those going on one side of the way, will, on the wall, seem to be walking in the opposite direction. Now the same certainly happens to the eye, and it is a matter of astonishment, that we nevertheless see objects in their proper and natural position though the image of them is inverted on the eye.

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THE
WONDERS
OF THE
MICROSCOPE.

CHAP. I.

OF THE STRUCTURE OF THE DIFFERENT KINDS OF MICROSCOPES.

BY a microscope we understand an instrument for viewing small objects, rendering those visible which would be otherwise imperceptible. There are many kinds of microscopes, which vary in their structure according to the fancy of the artist; but there are only three grand distinctions in principle, namely, the *single*, the *compound*, and the *solar* microscopes. The *single* microscope consists of *one* lens only; the *compound* microscope consists of two or more lenses; and the *solar* microscope is used in a dark room, the object being illuminated by the sun's rays and a small reflector or looking-glass. These instruments assist the eyes in examining the minute parts of creation, and bring into view wonders of a different, though not of a less extraordinary nature, than those perceived by the telescope. They exhibit the animal economy to be as perfect in the mite as in the elephant.

The human eye is so constituted, that in general we cannot see an object very distinctly when it is nearer the eye than about five or six inches; and if we bring it much nearer than this, it becomes quite confused. The design of the *single* microscope is simply to enable us to view objects nearer than can be done by the naked eye, because the apparent magnitude of any object becomes greater the nearer it is brought to the eye. Of this we may be convinced by a very simple experiment; and though readily made, and calculated to carry conviction to the mind, is rarely mentioned in books that treat on this subject. Make a small hole with a needle or pin in a sheet of brown paper, look through this at any object, as the print of a book: at the common distance for reading, no visible change takes place in the size of the letters; but bring the paper and the eye within an inch or two of the book, and the print is very much magnified. That is, the smallness of the hole admits comparatively only a few rays of light to the eye, by which it is enabled to see the letters in the book, or any other object, much nearer than it could without the intervention of the brown paper; and, as we said, the nearer the object is brought to the eye, the greater will be its apparent magnitude. This, therefore, may be called a sort of single microscope without the interposition of any lens.

When, however, a lens is interposed between the object and the eye, the effect is more perfect; for, by the help of this, we unite in the same sensible point a great number of rays, proceeding from one point of an object; and as each ray carries with it the image of the point from whence it proceeded, all the rays united must form an image of the object from whence they were emitted. This image is *brighter*, in proportion as there are more rays united; and more *distinct* in proportion as their natural order is preserved. In other words, a single microscope removes the confusion that accompanies objects when seen very near the eye; and it magnifies the diameter of the object in the proportion of the *focal distance*, to the limit of distinct vision, which is reckoned eight inches. Thus, if the semi-diameter of a convex lens be half an inch, which is also its focal distance, the magnifying power of such a lens is as 8 to $\frac{1}{2}$, or as 16 to 1; that is, the length of the image will appear sixteen times larger than the length of the object itself. If instead of half an inch it were only a quarter or a tenth of an inch, in the former case the magnifying power would be as 8 to $\frac{1}{4}$, or as 32 to 1; in the latter it would be as 8 to $\frac{1}{10}$, or as 80 to 1. Hence it follows, (as the distance of eight inches always remains the same) that the smaller the focal distance, or, which is the same thing, the smaller the little globule that is used as a lens, the greater will be its magnifying power.

A drop of water is a microscope of this kind; for if a small hole be made in a plate of metal, or other thin substance, and carefully filled with a drop of water, small objects may be seen through it very distinctly, and magnified. Small globules of glass are much more convenient, and better adapted to use: and as these have been found very fit for the purpose, we may point out the mode by which they are made.

Take a very thin slip of clear glass, and melt it in the flame of a candle or lamp, and draw it out into exceedingly fine threads. Melt the end of one of these threads in the same flame till it run into a small drop, which, when cool, may be fixed in a thin plate of brass or silver, so that the middle of it may be directly over the center of a very small hole made in this plate. By these very simple means, Dr. Hooke says, he was able to distinguish the particles of bodies not only a million times smaller than a visible point, but even to make those visible, of which a million of millions would hardly make up the bulk of the smallest visible grain of sand.

The compound microscope consists of, at least, two convex lenses, an object-glass and an eye-glass. By the former, the image of the object is formed, which image the eye is enabled to view distinctly, at a near distance, by the help of the latter. Through this microscope, an object appears magnified on two accounts; for, first, the image itself is larger than the object; and, secondly, we are able to view it distinctly at a less distance. If, for instance, the image be twenty times larger than the object, and if by the help of the eye-glass we are enabled to view it five times nearer than we could have done with the naked eye, it will on both accounts together be magnified 5 times 20, or 100 times. These kind of microscopes have usually two eye-glasses, which give a much larger field of view, and likewise increase their magnifying power.

The first plate is a representation of a compound microscope, with the apparatus that is usually sold with it. The large figure represents the microscope, which is made of brass, and about eleven or twelve inches in height. In the large tube A, a smaller one B, containing the lenses, slides up and down. At the upper part *a* are contained two eye-glasses combined together, and at the lower part *b* the magnifiers are screwed. With a microscope of this kind there are four, five, or six magnifiers, marked 1, 2, 3, &

&c. No. 1. being that which magnifies the least, and No. 6 that which magnifies the most. Underneath the magnifier is *c*, a kind of spring placed to receive the sliders, such as that represented by Fig. 2. C is a glass concave mirror which turns all ways to reflect the light from a window or candle through the hole *c* into the body B.

Fig. 3. represents nippers for holding or supporting living insects, seeds, &c. by means of the pin *p* it is fitted to the hole *d* of the stage, Fig. 1. and either end, with the object, may be readily brought under the magnifier *b*.

Fig. 4. is a small glass tube capable of containing a live fish, in order to observe the circulation of the blood. Fluids of any kind may also be put into it; and when corked at the open end, it is to be brought to the spring wire under the stage *d*.

Fig. 5. is a brass hollow cone to be occasionally placed under the stage *d* to diminish the quantity of light reflected from the mirror C.

Fig. 6. is a pair of brass forceps to take up any minute object.

Fig. 7. represents a round piece of glass, which is to be applied to the center of the stage when the slider holder is removed. There is also fitted to the same hole a concave glass to combine with this, so that animalcules, small transparent living objects, &c. may be secured, and viewed in a proper manner.

Having described the several parts of the microscope, it is unnecessary to say any thing about its use, as a young person will learn this the best by once seeing it in the hands of some experienced person.

The *solar* microscope is the last that seems necessary to be described in this little work. In this instrument, which is much the pleasantest for general use, the image of the object is thrown upon a screen in a darkened room, and the picture thus formed will be larger than the object, in proportion to the distance of the screen from it; so that a small object, such as a mite, may be magnified to the size of eight or ten feet in diameter.

The solar microscope is composed of a tube, a looking-glass, a convex lens, and a common microscope. The tube is made of brass, about two inches in diameter, which, turning round at pleasure in a square frame, may be easily adjusted to a hole in the shutter of a window, in such a manner, that no light can pass into the room but through the tube. The looking-glass is fastened to the frame by hinges, on which it may be turned all ways to throw the sun's rays through the tube into the darkened room. The end of the brass tube, without the shutter, has a convex lens, to collect the rays, and bring them to a focus, and on the end within the room a small microscope is screwed, with the object to be examined applied to it on a slider. The sun's rays being directed by the looking-glass through the tube upon the object, the image or picture of the object is thrown distinctly and beautifully upon a screen of white paper, &c. and may be magnified to almost any size.

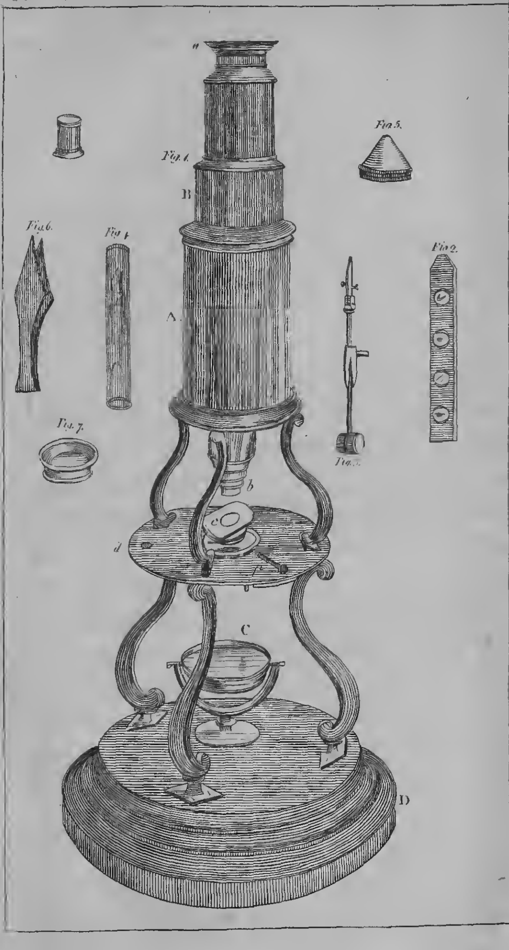
CHAP. II.

OF THE DISCOVERIES MADE BY THE ASSISTANCE OF THE MICROSCOPE.

MICROSCOPES have brought us acquainted with a new world of vegetables and animals, and have demonstrated to the careful observer, that there is no less of order and harmony in the construction of the mite, than in that of the whale or the elephant. The only difference is, that the weakness of our sight prevents us from penetrating into the nature and organization of small bodies, which often escape our eyes, and which can only be perceived by the assistance of glasses. These teach us, that the smallest objects, of which our forefathers had not the least knowledge, have extension, parts, and a well organized form. The mention of some examples will lead us to acknowledge the power, wisdom, and goodness of that God upon whom we all depend for existence and happiness.

Grains of sand, which appear of the same form by the naked eye, will, when seen through

Plate 1.



through a microscope, exhibit different shapes and sizes. Some are perfectly globular, others square, others conical, and for the most part they are irregular. But what is still more surprising, the cavities in these small grains of sand have been found, by the microscope, to contain insects of various kinds. In cheese that is decayed, there are a multitude of little worms called mites, which, to the naked eye appear like moving particles without shape or order; but, by the help of the microscope, they are found, as we shall see hereafter, to be of a very curious and singular figure. They have not only eyes, mouth, and feet, but a transparent body, furnished with long hair, in the form of prickles.

The mouldy substance which sticks to damp bodies, exhibits a region of minute plants; sometimes it puts on the appearance of a forest of trees, in which the branches, leaves, flowers, and fruits can be clearly distinguished. Some of the flowers have long, white, transparent stalks; before they open, the bud is but a little green ball, which becomes white as it blows. The particles of dust which cover the wings of the butterfly, are proved by the microscope to be beautiful and well-arranged little feathers:

> In down of ev'ry variegated dye,
> Shines fluttering soft the gaudy butterfly;
> That powder which thy spoiling hand disdains,
> The form of quills and painted plumes contains;
> Not courts in more magnificence express,
> In all their blaze of gems, and pomp of dress.
>
> BROWNE.

And if we examine by the same instrument, the surface of our skin, it will be found to resemble the scales of a fish; and so minute are these scales, that it has been computed a single grain of sand would cover 250 of them, and that a single scale covers 500 pores, through which the insensible perspiration, so necessary to our health, is continually going on; therefore, according to this calculation, a single grain of sand is large enough to cover 125,000 pores of the human body.

The microscope displays to us, in each object, a thousand others which escaped our knowledge. Yet, in every object discovered by this instrument, others yet remain unseen, which the microscope itself can never bring to notice. What wonders should we see, if we could continually improve those glasses, which are invented for the assistance of our sight. Imagination may, in some measure, supply the defect of our eyes, and make it serve as a mental microscope to represent in each atom thousands of new and invisible worlds.

How many objects in nature are concealed from our view! What we know is very small in comparison of the whole of the works of the Almighty; but, imperfect as our knowledge is, we are sure that the Creator has displayed as much wisdom in the formation of the least objects, as in the greatest. He provides with the same kind and parental care for the wants of the insect that crawls in the dust, as for the whale, which appears as a huge mountain in the mighty seas. In this may we, may the young in particular, imitate the example of the Deity, by shewing kindness and humanity to every living creature, since, as they are worthy of His care, they ought not to be ill-treated by us:

Nor power alone confess'd in grandeur lies,
The glittering planet, or the painted skies;

Equal the elephant's or emmet's dress,
The wisdom of Omnipotence confess;
Equal the cumbrous whale's enormous mass,
With the small insect in the crowded grass;
The mite that gambols in its acid sea,
In shape a porpoise, tho' a speck to thee!
E'en the blue down the purple plum surrounds,
A living world, thy failing sight confounds!
To thee a peopled habitation shows,
Where millions taste the bounty God bestows.

BOYCE.

CHAP. III.

THE SAME SUBJECT CONTINUED.

IN contemplating the works of God, we trace the effects of His wisdom and goodness, not only in the system of the universe, but also in the minutest parts of the creation. Divine wisdom is as evidently displayed in the spider's web as in those laws which connect the sun and the planets which revolve around him. The microscope discovers to the attentive observer new worlds, in which he beholds, in miniature, all that can excite his wonder, and lay claim to religious reverence. Those who have not the opportunity of examining the curious objects displayed by the microscope will be glad to know what has been seen by others, and what they themselves may hereafter contemplate with delight.

Consider the mosses and the grass with which the earth is covered, as with a carpet; of how many threads and small particles are those plants composed, and into which they may be divided. If the particles of water are so small, that millions of animalcules may be suspended on the point of a needle, how many must there be in the rivers and seas which cover so large a part of the earth? If from a lighted candle there issue, in a minute, many more particles of light than there are grains of sand in the whole earth, what must be the number that flow in a day, or a year, or a century, from the immense body of the sun? How indefinitely small must those particles of odoriferous bodies be which fill large spaces with their odour, for days and even weeks, without any sensible loss of their weight?

Let us pass to the animated creation. In a summer's evening the air swarms with living creatures. Each drop of stagnant water contains a little world of animated beings. On each leaf of a tree is seated a colony of insects; every plant, every flower, affords food for millions of creatures. Every person capable of observation and reflection must have seen the innumerable swarms of flies, gnats, and other insects collected together within their view, in the compass of a few yards! what prodigious shoals must there be over the whole earth, and in the immense expanse of the atmosphere! How many millions of still smaller insects and worms are crawling on the ground, or living beneath its surface!

The artificial convex will reveal
The forms diminutive that each conceal;
Some so minute, that, to the one extreme,
The mite a vast leviathan would seem;
That yet of organs, functions, sense partake,
Equal with animals of larger make.
In curious limbs and clothing they surpass
By far the comeliest of the bulky mass.
A world of beauties! that thro' all their frame,
Creation's grandest miracles proclaim.

BROWNE.

If experiments and observations, by means of the microscope, did not prove the fact, could it be imagined that there were animals a million times smaller than a grain of sand, and yet endowed with organs of nutrition, motion, &c.? There are shell-fish so small, that even through a microscope, they scarcely appear larger than a grain of wheat, and these are living animals enclosed in hard houses. How small is the mite, and yet this almost imperceptible atom, when seen through a microcope, is a hairy animal, perfect in all its limbs, active in all its motions; of a regular form, full of life and sensibility, and provided with all the necessary organs. This animal, which is scarcely visible to us, is made up of parts which are indefinitely smaller than the whole. How minute, for instance, must the particles of those fluids be which circulate through the veins of such animalcules!

One circumstance deserving our highest regard is, that the glasses which discover so many defects in the best finished productions of human ingenuity, shew us nothing in these microscopic *natural* objects but regularity and perfection. How inconceivably fine are the spider's threads! thousands of these threads would scarcely make the thickness of common sewing silk. These are but a few of the objects which might be enumerated to engage our attention in this important pursuit. Our imagination is lost in the two extremes of nature, the great and the small, and we know not in which most to admire the Divine Power,—whether in those immense globes which roll over our heads, or in those microscopic objects imperceptible to unassisted human vision. Whether with a Herschel we take a telescope, and compute the stupendous magnitude and velocity of a planet; or with a Hooke or a Baker survey through a microscope, the structure and conformation of a mite; in each we are compelled to admire and adore the wisdom and power of the Creator,

> Who gives its lustre to an insect's wing,
> And wheels his throne upon the rolling worlds.
>
> COWPER.

The knowledge we possess is enough to excite in every well-disposed breast emotions of love and gratitude towards that great and good Being who has formed us capable of contemplating the works of creation, and who has afforded us opportunities for extending our speculations even to periods and regions when the assistance of glasses will no longer be needed to display to the senses the wonders of creation; but when we shall readily perceive the design and construction of every object, and the connection which each has to others in the vast chain in which ourselves make so small a part; and when the distinction of great and small will be at an end; for then all will be great to us, and all will fill us with pious joy and admiration.

CHAP. IV.

OF THE POINT OF A SMALL NEEDLE: FORMS OF THE FLAKES OF FALLING SNOW: OF MITES FOUND IN CHEESE: AND OF THE FULL POINT USED IN PRINTING.

WE shall now proceed to notice some minute objects as seen through a microscope. The first is a piece of a small needle, (Plate II.) The point is so sharp that the naked eye is unable to distinguish any of its parts: but through a microscope it appears as in the figure at *a*, *a*, not round or flat, but uneven and irregular. The piece here represented is about one-twentieth part of an inch in length; and to the naked eye it appeared perfectly smooth and polished; but being magnified, what a multitude of holes and scratches are discovered! How rough the surface! how void of beauty! and how plain a proof the deficiency of art, whose productions, when most laboured, if examined with organs more acute than those by which they were framed, lose all their fancied perfection! Whereas, as we shall see in the works of nature, the farther our discoveries reach, the more sensible we become of their beauties and excellencies.

A B C represent small holes and roughnesses like those eaten into an iron bar by rust and length of time. D is some body sticking to it by accident. b b b shew the end where the small piece of the needle was broken off, in order to take a better view of it.

As sharp as a needle—is a common phrase, by which we intend to express the most exquisite degree of sharpness; and indeed a needle has the most acute point which art is capable of making, rude and clumsy as it appears when examined by the microscope. This instrument exhibits to us numberless instances in the hairs, bristles, and claws of insects, and also in the thorns, hooks, and hairs of vegetables, of visible points many thousand times sharper, with a form and polish that proclaim the omnipotence of their Maker:

> Thy microscopic glass, admiring, bring,
> And view the humble hornet's sharpen'd sting;
> Then on the slenderest needle turn the eye,
> And the vast difference in their points descry:

This, view'd, more polish'd seems, acuter far,
That, rough as from the forge some blunted bar.
God's smallest work all human skill degrades,
Foils the lost man, and sinks his worth in shades.

BROWNE.

The works of nature are no less admirable for their variety than for their beauty! even in such things as appear the most alike, a strict examination will discover differences beyond all human conception. We have observed that no two grains of sand are exactly similar; and flakes of snow afford an amazing variety of configuration, beauty, and size.

Dr. Hooke tells us, that catching the falling snow on a black hat, or a piece of black cloth, he first observed the curious figures of its flakes; and he presents us, out of a great variety, with the several beautiful forms given in Plate II. Every flake consists of six principal branches or stems, all of equal length, shape, and make, issuing from a centre. These stems in the same flake are commonly of the same make exactly, but different in different flakes; insomuch that Dr. H. says, he has observed above a hundred different forms and sizes of these star-like flakes fall in a very little time.

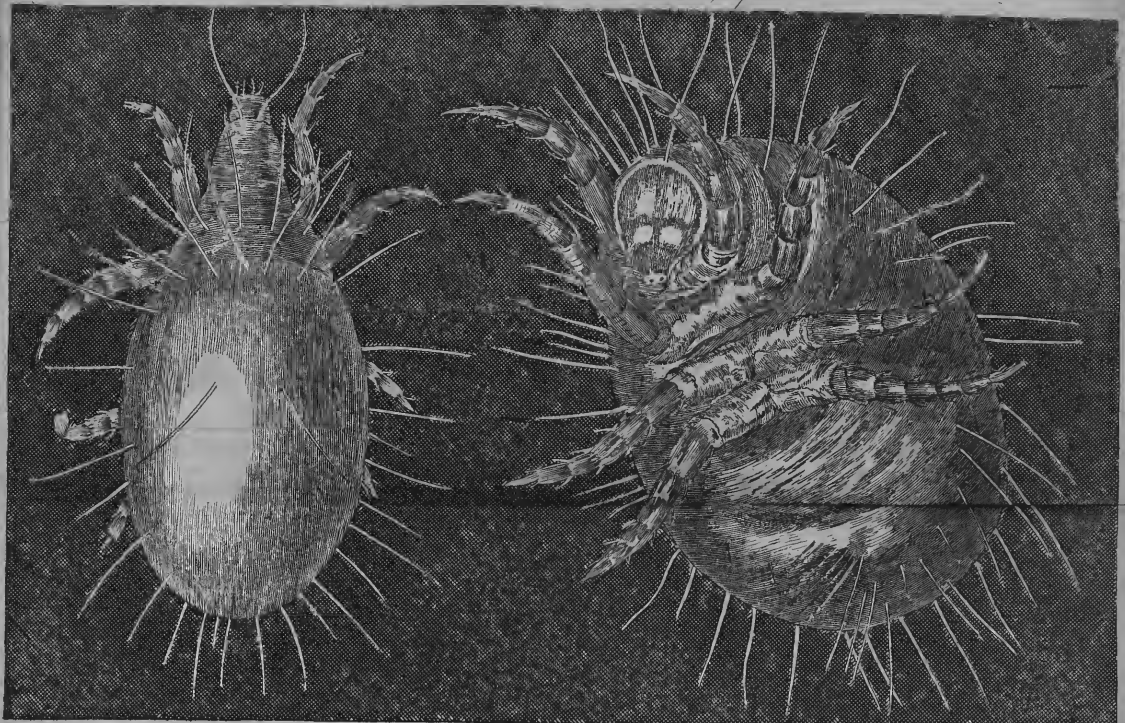
The rays which branch out from every stem in the same flake are so exactly alike, that by observing the configuration of any one stem, one may know certainly the figures of the other side.

A Cheese-Mite with its Back uppermost.

There are several species of minute creatures, which, from their extreme smallness and some resemblance in form, are called by the general name of *Mites.*

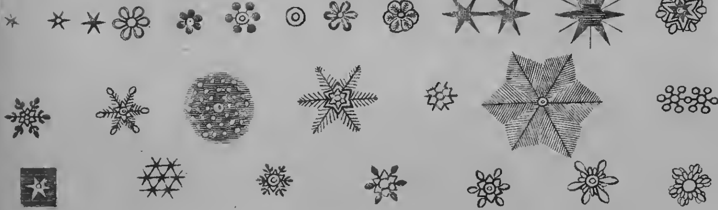
The first figure represents one of the mites found in cheese, placed in a crawling posture with the back part uppermost. The shape is a kind of oval, but more obtuse at the tail-end. It has three regions, or parts, as in the larger insects. The hinder part A, seems covered with one entire shell, so curiously polished, that, as in a convex mirror, it shews the picture of all the objects round about. The middle, or chest, seems divided and covered with two shells, which running one within the other, the mite is able to draw in or thrust out as it

The Mites in Cheese magnified.



The point of a very small Needle magnified.

Flakes of Snow, magnified.



A full Point magnified.

finds occasion; and it can do the same with its snout.

The whole body is of a pearl colour, and transparent; so that different motions of the intestines may be discerned. Several long white hairs grow in different places, some of which are longer than the whole animal. They all appear straight and pliable, excepting two, that issue from the head, which seem to be the horns.

A Cheese-Mite with its Back downwards.

The second figure shews a mite that was somewhat larger than the former, fixed on the back part of its tail, with a design of exhibiting the insertion of the legs.

To the small end of the oval body the head is fastened, in which a pair of eyes may be distinguished, appearing like two dark specks. The mouth resembles that of a mole, opening and shutting occasionally, and when open appearing red within. It has little bristles at the snout, and if viewed at a proper time, it is seen munching and chewing the cud like a *Guinea-pig.*

It is furnished with eight well-shaped and proportioned legs, covered with a very transparent shell; each leg has eight joints, fringed with several small hairs. The structure of the joints is the same as in crabs and lobsters, and each leg is armed with a very sharp claw at its end. Four of these legs are so placed as to move the body forwards; the other four, by being disposed in a contrary direction, are able to draw it backward when there is occasion.

Mites appear to the naked eye like dust in motion; the sharpest sight is unable to distinguish their parts, unless assisted by glasses. The females lay eggs, from which very small mites are hatched, of the same shape as their parents. These creatures shed their skins several times, and increase in size, but never change their form. A mite's egg is not more than a four or five-hundredth part of the size of a well grown mite, and such mites are not much above one-hundredth part of an inch in thickness: so that, according to this way of reckoning, a million of full-grown mites may be contained in a cubic inch, and five hundred times as many of their eggs.

For these amazing discoveries we are indebted wholly to the powers of the microscope.

scope. This instrument has given to the human race a new sense, and displays to us wonders never thought of by former ages.

Insignificant as the mite may appear to us, it is, with regard to the cheese on which it lives, as large and considerable as a man upon the earth. The insects that feed upon leaves, are, says a good writer, no bad representation of oxen grazing on immense pastures; and the animalcules, in a drop of water, swim about with as much freedom as whales do in the mighty ocean.

The remaining figure in this plate represents the *dot* produced in printing, which to the naked eye is perfectly round and well defined, but seen through a microscope, like the point of a needle, it exhibits the imperfections of art when compared with the precision of nature.

> Search the least path creative pow'r has trod,
> How plain the footsteps of th' apparent God!
> His art could organs, strength, and sense implant
> In the small agile fly, and reptile ant:
> In the mean mite, so much minuter still,
> Thy finger's pressing point may millions kill.
>
> BROWNE.

CHAP. V.

OF A FLEA, AS SEEN THROUGH A MICROSCOPE.

THOUGH the flea is almost universally known to be a small brown skipping animal, yet very few are acquainted with its real shape and figure, with the structure, strength, and beauty of its limbs and various parts, or with the manner of its generation and increase ; circumstances which could never have been discovered but by the assistance of the microscope.

The body of this creature is of an oval form, composed of several shelly scales, or divisions, most curiously jointed, and folding over one another ; those that cover the back meeting those that cover the belly, on each side of the body, and lying alternately over one and under another of them. Its neck is finely arched, much resembling a lobster's tail in shape, moving too, like that, very nimbly, by means of the jointing and folding over the scales that cover it.

The head is small and shelly, having on

each side a quick, round, and beautiful black eye, marked K in the plate, in the middle of which may be seen a round blackish spot, which is the pupil of the eye, encompassed with a greenish glittering circle or iris, as bright and vivid as the eye of a cat.

Behind each eye a small cavity appears at L, which in a certain thin film, beset with many small transparent hairs, may be observed moving to and fro; this is probably the ear.

From the snout part proceed the two fore-legs, and between them are two long small feelers or smellers MM. Each of them has four joints and abundance of little hairs. Just below, and almost between these horns, lies the proboscis or piercer NNO, consisting of a tube NN, and a tongue or sucker O, which can be put out or drawn in at pleasure. It has also two chaps or biters, shaped somewhat like the blades of a pair of round topped scissars, appearing to open and shut after the same manner. The flea, with these instruments, penetrates the skin of living creatures, and leaves a round red spot behind it, which we commonly term a flea-bite.

All the shells and scaly coverings of this small insect are most exquisitely polished, and in colour they resemble fine tortoiseshell; the scales on the back and belly have each of them, along its middle, a row of strong sharp bristles pointing towards the tail, like the quills of a porcupine, and in proportion to the animal they are as large. The neck and shoulders are likewise armed in the same manner, and great numbers of bristles are placed about the tail.

But the curious structure and contrivance of its legs are more particularly deserving our examination and praise; being such as have not been discovered in any other creature, and are adapted peculiarly to the exigencies of the flea: for as it lives by sucking human blood, or the blood of other animals, which cannot be obtained without inflicting wounds and causing pain, which must necessarily produce resentment and a desire of revenge, it was absolutely requisite that the little invader should have some ready means of escape, since every meal must otherwise be paid for with its life. As therefore it has no wings, its safety must be entirely owing to its legs; and indeed they are most excellently fitted for this purpose, by folding a short one within the other, and then by stretching them out to their whole length with a sudden spring or jerk, they commonly deliver the little animal from the danger of a pursuit.

The parts AA of the fore-legs, lie within the parts BB, and those again within the upper and stronger parts CC, parallel to, or side by side with each other. But the parts of the two next legs are disposed directly contrary to these; for in them the parts DD are placed without the parts EE, and the parts EE are still more outward than the parts FF. In the hinder legs the parts G, H, and I, bend one within another, like the limbs of a double-jointed rule; or like the foot, leg, or thigh of a man. When the flea intends to leap he folds up these six legs together, and then throws them all out at the same instant; and thereby exerting its whole strength at once, he carries his little body to a considerable distance. His legs have three principal and larger strong parts, and below them many small joints or divisions, as in the legs of a fly; from every joint proceed long hairs or bristles, and each foot is furnished with a pair of long hooked claws or talons, that in his leaping he may fasten and cling the better to what he lights upon.

Fleas are produced from eggs, which the females, by a kind of glutinous moisture, stick fast to the roots of the hairs of cats, dogs, and other animals, and also to the wool in blankets, rugs, and other similar furniture. Of these eggs a female lays ten or twelve a day, for several days successively; and they hatch in the same order about four or five days after their being laid.

From these eggs proceed little whitish worms or maggots, whose bodies have annular divisions, and are thinly covered with long hairs. They adhere closely to the body of the animal on whose juices they feed; or they may be kept in a box, and brought up with dead flies, which they eat with greediness. They are very brisk and nimble, and crawl like caterpillars, with a lively and brisk motion.

After eleven days from the time of their being hatched, they forbear to eat, and lie quiet, seemingly as if dying: but if viewed with a microscope, they will be found weaving a covering or bag round them, with a kind of silk emitted out of their mouths. In this bag they put on the chrysalis or aurelia form, and become milk-white. They continue nine days under this appearance, their colour darkening by degrees, and acquiring firmness and strength. As soon as they issue from the bag they are perfect fleas, and are able to leap away.

It has been discovered by putting the eggs of fleas in a small glass tube, and keeping it constantly warm in one's bosom, that in summer they hatch in four days; then, feeding the maggots with dead flies, in eleven days they come to the full perfection of the reptile state; then the maggot spins its bag, and in four days more changes into a chrysalis; after lying in this condition nine days, it becomes a perfect flea, and in three or four days it is capable of laying eggs. Thus, in about twenty-eight days, a flea may come from the egg itself, and propagate its kind. The vast increase of these insects, therefore will not seem so surprising, if it be considered that from March to November or December there may be seven or eight generations of them. After having laid their eggs they soon die, like all other creatures that undergo similar changes.

A flea may be dissected easily in a small drop of water upon a slip of glass, that may then be applied to the microscope. If this be done dexterously, the stomach and bowels, with their peristaltic motion, may plainly be distinguished, together with the veins and arteries, which are minute beyond all conception.

Two things in this creature merit consideration, namely, its surprising agility, and its prodigious strength, by which it is enabled to leap above an hundred times its own length. What vigorous muscles! and how weak and sluggish, in proportion to its own bulk, is the horse, the camel, or the elephant!

The same may be said of many other insects; a mite, for instance, how much swifter, comparatively speaking, does it run than the race-horse! A philosopher has computed the velocity of a little creature, scarcely visible by its smallness, which he found to run three inches in a second: now, supposing its feet to be the fiftieth part of a line, it must make five hundred steps in three inches, that is, it must shift its legs five hundred times in a second.

How sweet to muse upon His skill display'd,
Infinite skill! in all that he has made
To trace in nature's most minute design,
The signature and stamp of Pow'r divine;
Contrivance exquisite, express'd with ease,
Where unassisted sight no beauty sees;
The shapely limb, and lubricated joint
Within the small dimensions of a point;
Muscle and nerve miraculously spun:
His mighty work who speaks, and it is done;
The invisible in things scarce seen reveal'd,
To whom an atom is an ample field.

COWPER.

CHAP. VI.

OF THE LOUSE, AS SEEN THROUGH THE MICROSCOPE.

IN this case (Plate IV.) as in that of the flea, the figure of the louse is magnified to so great a degree, that every part may be perfectly known and distinguished; and, indeed, the outer coats of this creature are so transparent, that the internal structure, disposition, and motion of its bowels, and their contents, may be discerned, by the help of good glasses, without any difficulty. It is represented with its belly upwards, grasping a hair between its claws.

The head A bears a distant resemblance to a cone, but is a little flatted on the upper and under part. On each side, where the head is widest, a large shining black eye appears, very protuberant, and encompassed with a number of small hairs. These eyes BB, are situated a little behind the head, in the place where the ears of other creatures stand; and where one might expect to find the eyes, a couple of horns come out CC, extending themselves in such a manner, that they defend the eyes from being injured by the hairs through which they pass. Each of these horns has four joints, fringed with small bristles.

The head grows tapering from the horns to the top of the snout D, which ends in a sharp point, and seems to be a tubular instrument by which the louse sucks the blood of the animal it feeds and lives on; it is likewise probably the sheath of a piercer that serves to penetrate the skin for the blood to issue out.

In the position before us, there seems to be a resemblance of chaps or jaws, as at the letters EE; yet, when placed in another view, those lines or appearances are not discernible. Swammerdam says, it has no mouth that opens; and Dr. Hooke observes, that having kept several of them in a box for two or three days, by which they were become extremely hungry, upon letting one creep on his hand, he found that it immediately began sucking; and though it neither seemed to thrust its nose very deep into the skin, nor to open any kind of mouth, he could plainly discern a small current of blood passing directly from its snout into its belly; and there appeared about A some contrivance like a pump, a pair of bellows, or heart, which by a very swift and alternate dilation and contraction drew up the blood from the nose and forced it into the body. Though he viewed it very attentively while sucking, he could not perceive that any more of its nose was thrust into the skin than the tip of the snout D; nor did it give him the least pain, notwithstanding the blood ran through its head very quick and freely; which fully proves that blood-vessels are dispersed through every part of the skin, nay, even into the cuticula; for had its whole snout been thrust in from D to CC, it would not have amounted to the supposed thickness of that tegument, the length of the whole nose not being more than the three-hundredth part of an inch.

The thorax or breast is covered with a thin, transparent, horny, or shelly substance, which did not shrink or become shrivelled by the creature's fasting, as the covering of the belly did. Through this our author could plainly distinguish that the blood sucked from his hand was variously distributed, and moved to and fro; and within there appeared something that resembled a bladder, contracting and dilating upwards and downwards from the head towards the tail. Across the breast were many small milk-white vessels running between the legs; and sending to them innumerable minute branchings, which no doubt are veins and arteries; for in most insects the juices analagous to blood are white.

The louse has six legs, which are strongly jointed to the thorax; and for each pair a kind of division appears thereon, as *e e e*. They are covered with a kind of transparent shell, and jointed exactly like the legs of a crab or lobster. Each of them is divided into six parts, having several small hairs issuing from them, ending with two claws of unequal lengths, properly adapted to the particular exigencies of the animal, which has occasion to walk either on skin or hair. For the lesser claw *a* being so much shorter than the other claw *b*, when it walks on the skin the shorter claw does not touch, and then the feet are the same as those of the mite and many other insects: whereas, when amongst hairs, the longer claw can bend itself round by means of its small joints, and meeting with the shorter, can both together take hold and grasp a hair, as with a thumb and finger, after the manner represented in the figure, where FFF, the hair of a man's head, is so grasped and held fast by this creature, that it is in no danger of falling from it.

The belly is likewise very transparent; but its covering bears the resemblance of a skin rather than a shell, being grained all over just like the skin of a man's hand, and when the belly is empty, growing very flaccid and wrinkled.

The white spot II, may be the liver or pancreas, which, by the peristaltic motion of the intestines, is moved a little to and fro, with a thronging or justling motion.

After one of these creatures had fasted two days, all the hinder parts appeared lank and wrinkled; the white substance II scarcely moved; most of the white branches disappeared, as did also the redness or sucked blood in the intestines; the peristaltic motion of these was scarcely discernible;

but upon being suffered to suck, the skin of the belly, and the six scalloped embossments on either side, were quickly filled out; the stomach and intestines seemed quite crammed, and multitudes of white vessels appeared full and turgid; the peristaltic motion grew quick, as well as the justling motion of the substance II.

On this occasion the animal was so voracious, that though it could contain no more, it continued sucking as greedily as ever, and at the same time emptied itself as fast behind, which proved that its digestion must be very rapid; for though the blood, when first drawn into his body, appeared thin and black, it soon became in the intestines of a ruby colour, and that part of it which was carried into the veins was evidently white.

Near the bottom of the belly appears the anus K, beset with hairs or bristles; just below are two parts LL, which serve occasionally to close the aperture of the anus. At the extremity of the tail are two bodies MM, resembling the rump of fowls, and from these a number of sharp hairs issue.

If a louse be placed on its back, as in the plate, two darkish bloody spots appear; the larger in the middle of the body, and the lesser towards the tail. In the former a white bladder contracts, and dilates upwards and downwards from the head towards the tail, the pulse of which is followed by a pûlse of the dark bloody spot, and in or over this the white bladder seems to lie. The white bladder seems to be the heart, for on pricking it the louse instantly dies.

There are male and female lice; and Mr. Leeuwenhoek, a gentleman who made many discoveries by means of the microscope, found that the males have stings in their tails, but the females none; and he supposes, that the smarting pain they sometimes give arises from their stinging, when rendered uneasy by pressure or otherwise; since, if roughly handled, they may be seen to thrust out their stings: but he says that he felt but little pain or uneasiness from the piercer, though he suffered seven or eight to feed on his hand at once. The females lay eggs or nits, whence young lice proceed, perfect in all their parts, and they undergo no farther change but an increase in size.

To know from accurate experiment in what time and numbers these animals increase, Mr. Leeuwenhoek put two females into a black stocking, which he wore night and day; and found, that in six days, one of them had laid fifty eggs; and, upon dissecting it, he saw as many more in the ovary, from which he concludes, that in twelve days it would have laid an hundred eggs. These eggs hatching in six days, would probably produce fifty males, and as many females; and the latter coming to full growth in eighteen days, might in twelve days more lay also an hundred eggs, which eggs, in another week might produce a younger brood of five thousand; so that in about eight weeks a louse may see five thousand of its own descendants—an increase that might be doubted were it not proved by experience.

All vermin adhering to and feeding on the bodies of different animals, though very dissimilar in form and size, are usually called lice. Of these there are numberless species. Even insects are infested with vermin that feed on them and torment them. The *earwig* is frequently troubled with minute insects, especially just under the setting on of its head. They are white and shining like mites, but smaller. *Snails* of all kinds, but chiefly the large ones without shells, have many little insects, extremely nimble, that live and feed on them. Numbers of little red lice, in shape resembling a tortoise, are often seen about the legs of *spiders.* Whilst the spider lives they cling closely to it, but if it dies they leave it.

Those who have made the most minute and accurate researches into the several objects subjected to their senses, have found that the substances on which they employed their curiosity, were often totally different from what they expected. Thus an infinite number of animalcules are perpetually floating in the air we breathe, sporting in the fluids we drink, or adhering to the several objects we see and handle.

Whitish lice are sometimes discovered

running nimbly on *humble-bees*, on *ants*, and even on *fishes;* and, perhaps, few creatures are so small that smaller ones do not prey on them.

> Far less than mites, on mites they prey;
> Minutest things may swarms contain;
> When o'er your ivory teeth they stray,
> They throb your little nerves with pain.
>
> SAVAGE.

CHAP. VII.

OF THE FLY AND ITS SEVERAL PARTS.

THE common fly is adorned with beauties not to be conceived without the aid of a microscope. It is studded from head to tail with silver and black, and its body is covered all over with bristles pointing towards the tail. The head contains two large eyes, encircled with borders of silver hairs, a wide mouth, with an hairy trunk or instrument to take in its food, a pair of short horns, and several stiff black bristles. Its trunk consists of two parts, folding over one another, and sheathed in the mouth. The extremity of it is sharp like a knife, for the separation of any thing. The two parts can also be formed occasionally into a pair of lips for taking proper quantities of food; and by the fly's sucking in the air, they become a kind of pump to draw up the juices of fruits or other liquors.

Some flies are more transparent than others, and in such the motion of the intestines may be seen very distinctly, working from the stomach downwards; and also the motion of the lungs, contracting and dilating themselves alternately. On dissecting a fly, numberless veins may be discovered dispersed in all directions over the intestines; these are plainly visible by the microscope, though two hundred thousand times slenderer than the hair of a man's beard.

In most kinds of flies the female is furnished with a movable tube at the end of her tail; by extending this she can convey her eggs into convenient holes, in flesh, or other substances, that may afford proper nourishment to the young ones. From the eggs proceed minute worms or maggots, which, after feeding for a while in a voracious manner, and arriving at their full growth, are transformed into little brown *aurelias*, and from these issue, after a short time, perfect flies.

It would be an endless task to enumerate the different sorts of flies which may continually be met with in the meadows, woods, and gardens; and impossible to describe their various plumes and decorations, surpassing all the magnificence and luxury of dress in the courts of the greatest princes. Every curious and attentive observer, who is in possession of a good microscope, will attend to them for himself, and, with amazement and humble adoration, carry his thoughts from the creature to the Creator.

We must again, however, warn our young friends never to put an animal or an insect of any kind to pain for the sake of gratifying their curiosity. The legs and wings of flies, and other parts of these creatures, will, in the summer season, be readily found in windows; and frequently whole flies of all descriptions already dead, on which they may make their observations. Having said thus much, we will now give a brief description of the several objects that are given in the plate.

Figure 1, Plate V. is the *foot of a fly*, which consists of three joints, two talons, and as many pattens or spongy substances. By the wonderful contrivance of these, this creature is enabled to walk perpendicularly upwards, even against the sides of glass; nay, to suspend itself, and walk with its body downwards, on the ceilings of rooms, and the under surfaces of other things, with much facility and firmness.

The two talons are handsomely shaped, in the manner represented, as AB and AC, and are very large in proportion to the rest of the foot. The bigger part of them, from A to *dd*, is bristled, or hairy all over; but from thence towards C and B, the tops and points which turn downwards and inwards, are smooth and very sharp. Each talon moves on a joint at A, by which the fly is able to shut or open them at pleasure: so that the points B and C, having entered the pores of any thing, and the fly endeavouring to shut its talons, they not only draw against and by that means fasten each other, but also pull forwards all the parts of the foot; and at the same time the tenters or sharp points GGGG run into the pores, if they find any, or, on a soft place, make their own way.

Something of this kind may be discerned by the naked eye in the feet of a chafer; and if it be suffered to creep over the hand, or any tender part of the body, its manner of stepping will be as sensible to the feeling as to the sight.

But

But as the chafer, notwithstanding its contrivance to fasten its claws, often falls when it attempts to walk on hard and close bodies; so likewise would the fly had not nature furnished its foot with a couple of pattens or sponges DD.

From the bottom or under part of the last joint of the foot K, two small, thin plated, horny substances proceed, each consisting of two flat pieces DD. These, about FF, *ff*, seem to be flexible, like the covers of a book, by means of which the two sides *ee*, *ee*, do not always lie in the same plane, but may sometimes shut closer, so that each of them can take a little hold. But this is not all; for the bottoms of these spunges are every where beset with small bristles or tenters, like the wire teeth in a wool-card, with all their points inclining forwards; by which the two talons draw the foot forwards, as before described, and the spunges being applied to the surface of the body upon which the fly walks, with the points of all their bristles standing forwards and outwards, as expressed in the figure *o o o o o*, if the surface of the body has any irregularity, or gives way in any manner, the fly can suspend itself, or walk on it very easily and firmly. And its being able to walk on glass proceeds partly from some little ruggedness thereon, but chiefly from a kind of tarnish, or dirty smoky substance, which adheres to the surface of that hard body; so that although the sharp points on the spunges cannot penetrate the surface of glass, it may easily catch hold of the tarnish it has contracted.

yyy are some very long, stiff, sharp-pointed hairs or bristles.

A whole wing is exhibited in fig. 2. It consists of a fine, thin, transparent skin or membrane, variously folded, platted, or distended over the whole area; and several bones, ribs, or stems, disposed with great regularity and contrivance, so as to strengthen and support the wing, and determine its proper figure.

The bones or ribs of the wing are covered with multitudes of little scales; but the fore-edge is armed with a number of little bristles, all the points of which are directed towards the tip of the wing: and even the whole edge all round the wing is covered with a small fringe, consisting of shorter and more slender bristles.

The fine membrane extended between these bony ribs is thickly set with innumerable minute sharp-pointed hairs or bristles, ranged in the most regular rows over its whole surface; and intermingled with these may be perceived a like number of little pits or black spots, which seem to be the roots of the hairs growing on the other side.

In several other flies there are infinite numbers of small fibres which cover both sides of this thin membrane, instead of minute hairs; and on most moths and butterflies, they not only resemble the feathers of birds, in the manner of their arrangement, but are variegated with the same kind of curious and lively colours which the feathers of birds exhibit.

There are fourteen thousand *hemispheres* or *eyes* distinguishable in the clusters of the drone fly, and each of these pearls or hemispheres is a perfect eye, being furnished with a cornea, with a transparent humour, and with a *uvea* or *retina*. The figure of each is also spherical, exactly polished, and very lively and plump, when the fly is living, as in greater animals; and likewise, as in them, dull, shrunk, and flaccid, when the fly is dead.

One of the clusters being cut from the head, and opened, a clear liquor was discovered by the microscope, immediately under the outward skin or covering, which seemed perfectly to resemble the cornea of a man's eye; and when a darkish matter that lay behind was removed, appeared transparent, with as many cavities within side, and ranged in the same order as the little hemispheres in its outer surface.

The most remarkable of all insects for its fine pearled eyes, is the Libella or Dragon-fly. Mr. Leeuwenhock reckons twelve thousand five hundred and forty-four lenses in each eye of this creature, or twenty-five thousand eighty-eight in both, placed in an hexangular position; each lens having six others round it. He observed likewise in the centre of each lens a minute transparent spot brighter than the rest, and supposed to be the pupil through which the rays of light are transmitted upon the retina. This spot had three circles surrounding it, and seemed seven times less than the diameter of the whole lens. He also numbered six thousand two hundred thirty-six pearls or hemispheres in a silk-worm's two eyes, when in the fly state: three thousand one hundred eighty-one in each eye of the beetle, and eight thousand in the two eyes of a common fly.

The eyes of other creatures are as it were multiplied by motion; whereas those of a fly are fixed and immovable, and can only see what lies directly before them; they are therefore very numerous, and placed in a round surface, some in a high, others in a low situation, to inform the fly of every thing in which it may be interested. It has a number of enemies; but with the aid of the eyes that surround its head, it is enabled to discover whatever danger threatens from above, behind, or on either side, even when it is in full pursuit of a prey directly before it.

These eyes or little hemispheres are placed, in all kinds of flies and aerial animals, in a very neat, regular, and admirable ordination of triangular rows, ranged as near to one another as possible, and leaving the least pits or furrows between them that can possibly be. But in crabs, lobsters, or shrimps, whose eyes are less pearled, the pearls are ranged in a quadrangular order, the rows intersecting at right angles, by which disposition their number on equal surfaces must be less; but, to make them a recompence for this, Nature has formed their eyes a little movable, whereas those of flying insects are all fixed.

The goodness of Providence is particularly distinguishable in the formation and situation of the eyes of different animals, in a manner most suitable to their different necessities and ways of living. In hares and rabbits, whose safety depends on flight, they are very protuberant, and placed so much towards the sides of their heads, that their two eyes take in nearly a whole sphere.

In cats the pupil being erect, and the shutting of the eye-lids transverse, they can so close the pupil, as to admit, as it were, only one single ray of light: and, on the contrary, by throwing all open, they can take in the faintest rays, which is an incomparable provision for animals that have occasion to watch and way-lay their prey both by night and day. But, besides this, some nocturnal creatures have a certain radiation or darting out of rays of light from their eyes, enabling them to catch their prey in the dark: and this most people have been witnesses of in cats.

Some writers have been of opinion that moles are blind; but greater diligence, and more experiments, have shewn them to have eyes most excellently fitted for their subterraneous way of life; not, indeed, much bigger than a large pin's head, but which it is supposed they have a faculty of withdrawing, if not quite into the head, yet more or less within the hair, as they have more or less occasion to employ or guard them.

The eyes of snails are placed at the end of their horns, and are thrust out at some distance, or drawn quite within the head, as the animal thinks proper.

Those of the camelion turn backwards, or any other way, like a lens or convex glass in a globular socket, without any motion of the head; and it is very extraordinary to see one of the eyes of this creature moving, while the other remains fixed; one turning forwards at the same time that the

Fig. 3. The Blue Bottle Fly in a Microscope Magnified.

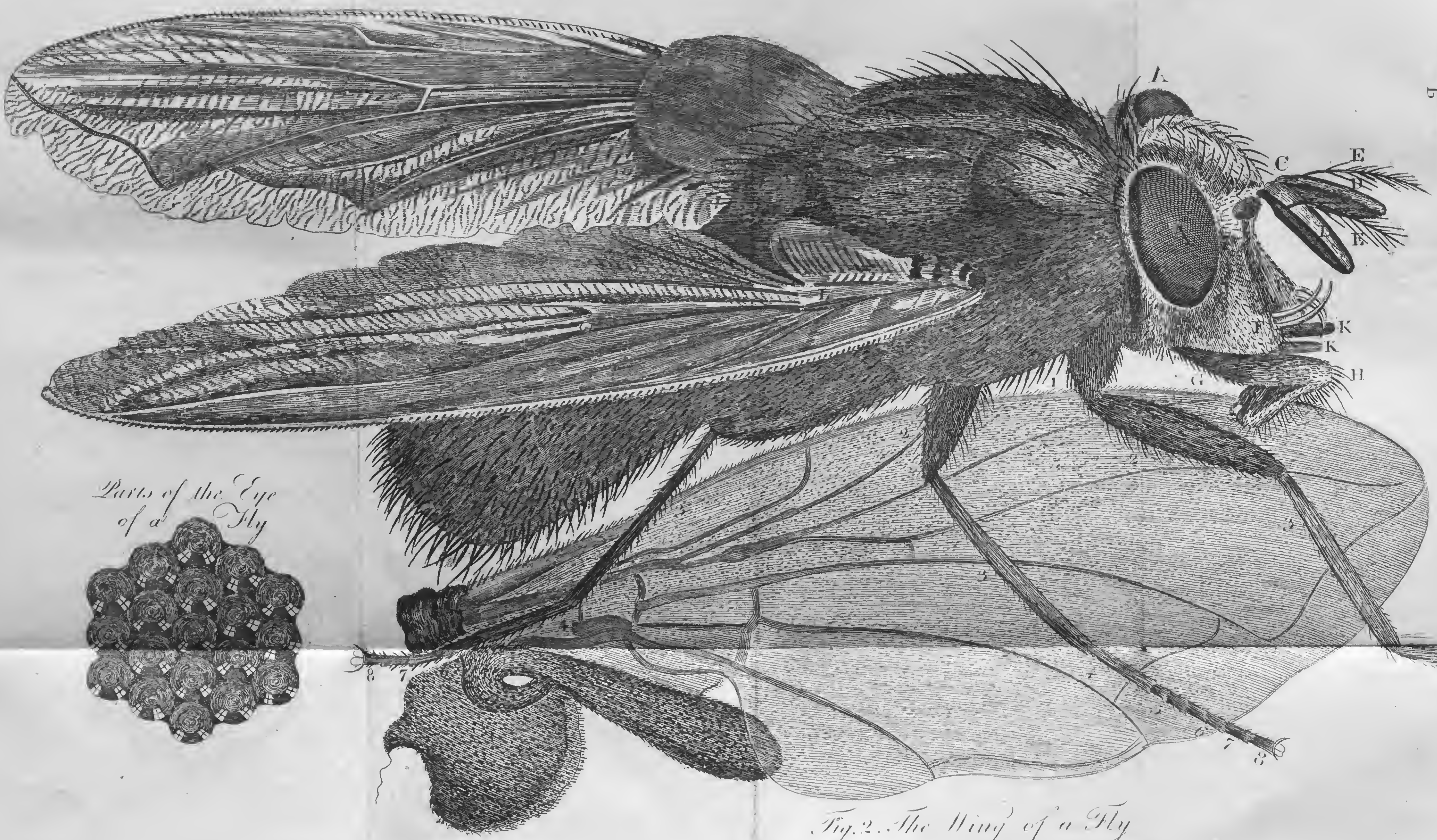


Fig. 2. The Wing of a Fly

Parts of the Eye of a Fly

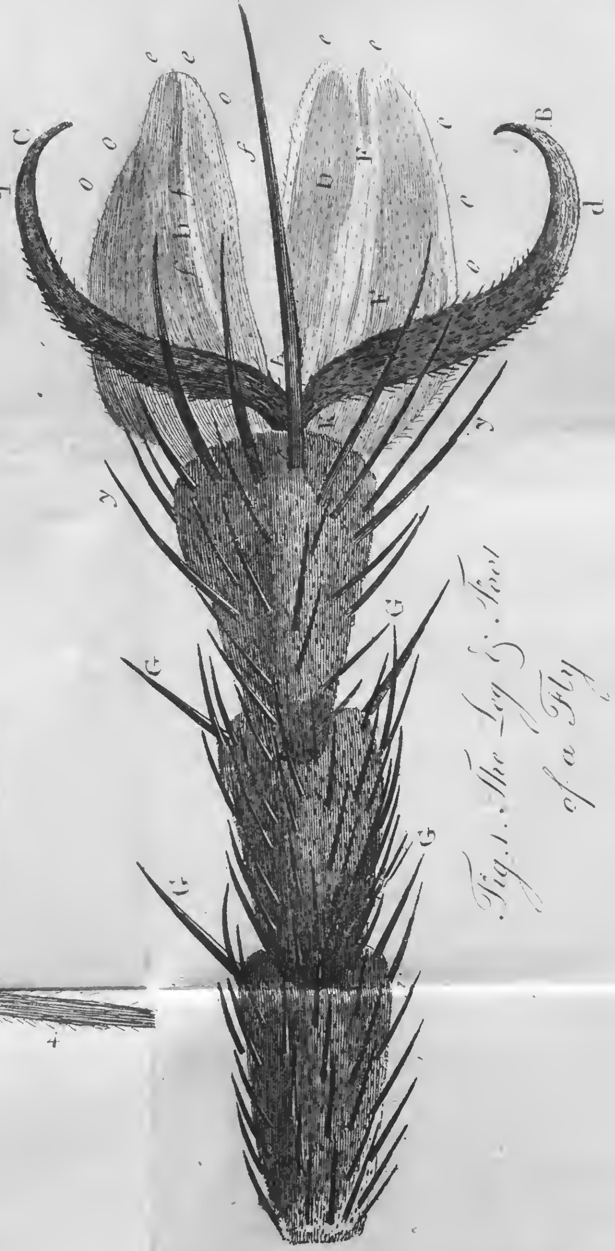


Fig. 1. The Leg & Foot of a Fly

other is looking behind; or perhaps one looking up to the sky, while the other turns itself downward towards the ground.

The blue-bottle, or common flesh-fly, enlarged by the microscope, in such a manner as to shew distinctly all its particular and minute members and ornaments, is exhibited in fig. 3. AA are its protuberant and pearled eyes, which make a considerable part of the head, though much smaller than those of the drone-fly. These pearls or hemispheres are ranged in triangular order.

A scaly prominent front between the eyes, adorned and armed with large tapering sharp black bristles, which growing on either side in rows, and bending towards each other near the top, form a kind of arch of bristles, that almost covers the front B.

C, a projecting part at the anterior end of this arch, and about the middle of the face, on which grow DD, two little oblong bodies, not unlike the apices or pendants in lilies, each having one small joint where it unites to C, and another that joins it to the front part B. These in the head of the drone-fly are called horns, from the great resemblance they bear to the horns of some kinds of beasts.

EE, are brushy bristles or feathers, somewhat like the tufts of a cock-gnat, growing from the upper part and outsides of the horns DD.

FF, are four strong bristles, placed two and two, and bending towards each other, just above the opening of the mouth.

GHI, is the fly's proboscis or trunk, coming out from the middle of the mouth. It seems to be a hollow body, and by means of several joints is moved to and fro, thrust out or pulled in at pleasure. There is a knee or bending expressed at H, which from thence to the extremity is slit, as it were, into two lips, HG, HI, which on their outer sides are covered with pretty large hairs; though the hairs on the upper part of the proboscis are very small. These lips open or shut easily, and serve to hold or take in little pieces of solid food; but when the fly sucks any thing from the surface of a body, she spreads them open and applies their hollow part perfectly close to them; in which condition they become a kind of pump, to draw up the juices of fruits or other liquors.

KK, are two little hairy oblong bodies, growing within the mouth, from each side of the proboscis. These parts are differently shaped, and much larger in the head of the drone-fly, where they are marked GG. Dr. Hook imagines these may probably be its organs of smelling.

The middle part, or thorax of this fly, is crustaceous, and strongly made, rounded on the top, and covered with large, long, black bristles, standing like the quills of a porcupine, in parallel order, all pointing towards the tail. From the hinder and under part grow out three large legs on each side (as represented in the figure), all covered with a strong hairy shell, and resembling the legs of a crab or lobster. Each leg is jointed, and made up of eight parts, 1, 2, 3, 4, 5, 6, 7, 8; on the eighth of which grow the soles or spunges, and claws.

Of these six legs the fly seldom employs more than four to walk with, the two former serving instead of hands, to take up any thing to eat, to clean her mouth, eyes, wings, and body, and for many other purposes.

LL, are the two wings fastened with

strong joints to the upper part of the thorax.

The hinder or tail part is of a most lovely shining blue, looking exactly like polished steel, brought to that curious colour by annealing; and seems like a kind of armour, thickly beset with bristles similar to those which grow upon its back.

In this and most kinds of flies, the female is furnished with a movable tube at the end of her tail, by extending which she can convey her eggs into convenient holes and receptacles, either in flesh or such other matters as may afford the young ones proper nourishment. From the eggs come forth minute worms or maggots, which, after feeding awhile in a voracious manner, and arriving at their full growth, become transformed into brown aurelia, whence, after some time longer, they issue perfect flies.

Upon opening a fly, numberless veins may be discovered dispersed over the surface of its intestines; for the veins being blackish and the intestines white, they are plainly visible by the microscope, though two hundred thousand times slenderer than a common hair.

According to Mr. Leeuwenhoek, the diameter of four hundred and fifty such minute veins were about equal to the diameter of a single hair; and consequently two hundred thousand of them put together would be about the bigness of a hair.

CHAP. VIII.

OF ANIMALCULES IN FLUIDS: HOW TO MAKE PEPPER WATER AND OTHER INFUSIONS; AND OF THE ANIMALCULES FOUND IN THEM: OF ANIMALCULES IN VINEGAR AND PASTE.

FROM particular objects we come to those which are more general; and in this chapter we shall describe those animalcules that are to be found in different fluids. These, or at least some of the species, are the smallest living creatures with which we are acquainted. By means of the microscope many kinds of animalcules have been discovered, as different from each other as the horse differs from the mouse; some indeed are so exceedingly minute, that a million of them would not be equal in magnitude to a large grain of sand; and as more and smaller objects have ever been discovered, in proportion to the goodness of the glasses with which they have been viewed, it is highly probable, that there are numberless other species of a size much less than those already discovered.

Here will be full scope for the enquiry and admiration of our young friends: every drop of water, and almost any fluid, except, perhaps, oils and ardent spirits, either is, or will, by standing exposed to the air, in warm weather, for a few days, be swarming with living creatures. Some of these seem natural inhabitants of the several fluids in which they are found: others live only there occasionally, in the manner of gnats, which from eggs dropped by their parents in water, become swimming animals; but after a short time, they shed their skins, appear in a form that bears no resemblance to what they had before assumed, take wing, and claim kindred with the countless millions which rejoicc in the air.

Mark'd by the magnifying chrystal's aid,
In ev'ry place what proofs will stand display'd!
Lo! from the stagnant pool one drop obtain,
Of insects this includes a sumless train:
Buoy'd in the little pool they frisk and play,
Pleas'd with their short existence of a day.

BROWNE.

Do you ask how it is that stagnant water, or water in which pepper, hay, or other vegetables are infused, will soon become full of life? The answer, founded upon unquestionable observations and accurate experiments, is, that those minute and invisible little flies which are every where floating in the air, and seeking places in which to deposit their eggs when they find a fluid stored with proper nourishment for their future offspring, may be supposed to resort to it in swarms, and lay their eggs there. These eggs being soon hatched, the infant brood swim about and live happily in it till grown to their stated size; they then, in due time, change their forms, employ their wings, and fly away.

Mr. Baker, whose observations on this subject were the most accurate, took every method to ascertain this fact; and he says, that, after carefully noticing some kinds of animalcules in several fluids to be grown to a certain size, on a sudden he found that they were all gone, and only a much smaller, and consequently a younger, race of the same species remaining; these also, when grown to a like size, have soon after taken their departure. Besides, if the infusion be covered, though with muslin or fine lawn, he constantly found that few animalcules would be produced in it; but, upon taking off the covering, it has, in a few days, been full of living creatures. This certainly goes to prove, that the eggs from which these animalcules proceed, must either be deposited by their own parents, or be brought with the air. Perhaps indeed it may happen from both ways; for, as the eggs of such minute creatures are lighter than air, and so small as not even to intercept the rays of light from the eye, millions may, in the proper season, be floating almost every where: in places unsuitable to their nature they will perish; but if they fall into a situation adapted to their support, they will hatch and come to perfection.

Though clear and pure water, will, after standing some time in the open air, have some animalcules, they will not be so numerous as when vegetable bodies have been steeped in it; for, perhaps no creatures, however small, can live upon water alone; but when it is stored with proper food, by an infusion of such substances as have been already mentioned, the microscope will exhibit to the admiring eye myriads of living creatures in every drop. But as those for whom this liltle book is designed may be desirous of viewing these wonders for themselves, and of exhibiting them to their youthful companions, the following very simple directions may not be unacceptable.

To make Pepper Water.

Put common black pepper, grossly bruised, into an open vessel, as a flat bottomed tea-cup, to cover the bottom of it about half an inch in thickness, then pour upon it rain or river water, till it rises above the pepper an inch or thereabouts. Shake or stir the mixture well, and then let it stand undisturbed in the open air. In a few days there will be a thin skin upon the water reflecting the prismatic colours. This skin, examined by the microscope, will be found to contain millions of animalcules; at first, indeed, scarcely discernible, even with the best magnifier, but continually growing larger till they arrive at their full size. Their numbers too will every day increase, till at length almost the whole fluid will seem animated and alive; though in reality they will be chiefly on the surface of the water, unless disturbed; but when that happens, they will sometimes dart down at once, and not appear again for some time. This experiment will succeed even in winter; but not so well as in warm weather.

To examine this scum, more of it should not be used than a quantity about the size of a pin's head, which may be taken up with the nib of a new pen, or a small hair pencil, and applied on a single isinglass, first to the third magnifier, then to the second, and afterwards to the first, which will shew several kinds of animalcules, differing in shape as well as in size.

The *largest* sort are thin and transparent: they turn themselves frequently in the water, having a great number of feet, which are frequently seen about the extremities; at one end there are likewise some bristles longer than the feet, resembling a tail. Their motion is swift, and by their frequent turns and sudden stops they appear to be hunting after their prey, which are probably insects indefinitely smaller than themselves,

selves, and which have hitherto escaped the notice of our best glasses. They can employ their feet in running as well as swimming; for, upon putting a hair among them, they will frequently, like rope-dancers, creep along it from end to end, bending in several odd postures.

The *second* kind have a screw-like form; sometimes when they lie still they thrust forwards and backwards a fringed or bearded tongue; a small current may be discerned running constantly towards them, which is caused probably by the nimble motion of some minute fins or legs too fine to be discerned.

Another sort, about the size of the last, but without tails, appear of a shape resembling a flounder; their feet may be seen very clearly as the water is evaporating, for then they move them nimbly.

The next kind appear like slender worms, about fifty times as long as they are broad; their motion is equal and slow, waving their bodies but little in their progression. They swim with equal facility backwards and forwards; and being every where of the same thickness, it is very difficult to distinguish at which end the head is placed.

A fifth sort are so small that an hundred of them in a row would not equal the diameter of a grain of sand; and consequently a million of them are but equal in bulk to one such particle: their shape is nearly globular.

A sixth kind have also been discerned about the thickness of the last; but twice as long.

The smallest drop of sulphuric acid, even as much as will stick to the point of a pin, put among these animalcules, will cause them all to fall down dead. A solution of salt or of sugar also kills them; so will ink, and even blood or saliva.

If the water be permitted to evaporate, some kinds of the animalcules will burst; but others, though apparently dead, will revive by supplying them with fresh water.

To make Hay Water.

New-made hay cut into small lengths and put into water, will in a few days produce a whitish scum on the surface, which when examined by the microscope, will be found to contain inexpressible numbers of minute living creatures of various sizes, forms, and kinds. Some of them are precisely the same as those described in the pepper water; but the most general among them is an oval sort of animalcule, something in the shape of an ant's egg. They are extremely nimble, and in a continual swift motion backwards and forwards: but sometimes they stop on a sudden, and turn round on their own axis many times with surprising velocity, first one way, and afterwards the contrary.

Another sort that is common to this infusion are clear and transparent, but curiously ribbed in the manner of a melon: others are transparent at their extremity only, and in these neither legs nor fins are discernible. There is likewise a species of animalcules, whose bodies are nearly spherical, but pointed at one end like a pear, and resembling bladders filled with water, in which a vast number of dark particles seem in continual agitation.

Animalcules in the shape of eels are frequently met with in many infusions, and in other liquors. The size of them is very different; some being an hundred times larger than others, and probably they differ very much in kind.

VINEGAR, after standing a few days uncovered, especially in the summer season, will abound with these insect eels, frequently large enough to be discerned by the naked eye. If the vinegar in which these abound be moderately heated at the fire, they will be killed, and sink to the bottom: cold does them no injury. Dr. Power put some vinegar full of these eels into a glass, and on it he poured an equal quantity of oil; he then froze the vinegar, which caused the eels to creep into the oil as a shelter; but, upon thawing the vinegar, they returned to it again. If a few very small grains of sand be put among the eels, they will appear embarrassed, and, as it were, struggling to free themselves among large stones.

Those who wish to be furnished with microscopic eels at all seasons, may have them in common paste, such as the book-binders commonly use. It should neither be too stiff nor watery. Expose it to the air, and prevent its hardening or becoming mouldy on the surface, by beating it well together when it has that tendency. After some days it will become sour; and then, if examined attentively by a microscope, multitudes of exceedingly small, long, and slender animalcules will be visible; these will grow larger till they are of sufficient size to be seen by the naked eye. A drop or two of vinegar should now and then be poured on the paste; and sometimes, to prevent its becoming too dry, a little vinegar and water. By this means microscopic eels may be had all the year. They must be applied to the microscope upon a single talc, after having first put on it a very small drop of water for them to swim in.

These are very entertaining objects when examined by any kind of microscope; but particularly the solar one, by which the motions of their intestines may very plainly be distinguished; and when the water is nearly dried away, and they on the point of expiring, their mouths may be seen opening to a considerable width.

CHAP. IX.

OF ANIMACULES FOUND IN STAGNANT WATER: OF GNATS, AND FROM WHAT THEY PROCEED: THEIR TRANSFORMATIONS: THE WHEEL INSECT.

MR. Leeuwenhoek, to whom we have often referred, says, that in rain water newly descended, no living creatures were to be discerned; but after standing some days, innumerable animalcules, many thousand times smaller than a grain of sand, were visible by the microscope. These were of different species, which need not be particularly described.

It is common in the summer for the water that stands in ditches to appear sometimes of a greenish and sometimes of a reddish colour, which, upon examination with the microscope, is found owing entirely to the millions of animalcules crowded together on the surface, and giving it that appearance. Their bodies are oval and transparent at both ends; but the middle parts are either green or red, according to the apparent colour of the water in which they are swimming. The middle part being viewed with the first or second magnifier, seems composed of globules, and bears so near a resemblance to the roe or spawn of fish, that it is generally believed to be the same, and the more so as they are found, after some time, perfectly clear and colourless, when they may be supposed to have shed their spawn:

> ———————— Where the pool
> Stands mantled o'er with green, invisible,
> Amid the floating verdure millions stray.
> ———————— Nor is the stream
> Of purest crystal, nor the lucid air,
> Though one transparent vacancy it seem,
> Void of their unseen people.
>
> THOMSON.

The water that drains from dunghills, and looks of a deep, brown colour, is so thronged with animalcules, that it seems to be all alive, and must be diluted with common water before they can be sufficiently separated to distinguish their various kinds.

An infusion of any herb, grain, fruit, or flower, made in common water, will be found, after a few days, to contain some kinds of animalcules peculiar to itself, which may readily be accounted for; since every herb, grain, fruit, or flower is allotted by Providence to be the food of some particular sort of bird, beast, or insect, of the visible or larger kinds, we may imagine it, in like manner, when infused in water, to afford a proper nourishment for some of those numberless species of minute creatures which are invisible to the naked eye, and not to be discovered without a good microscope.

Sometimes in the infusions of vegetable productions, and in other waters that have stood exposed to the open air, an animal is discerned much larger than any before described, of a very singular and surprising form. This little creature is in its middle state; it was late a worm, and will soon become a gnat:

> We wonder at a thousand insect forms
> These hatched, and those resuscitated worms,
> New life ordained, and brighter scenes to share,
> Once prone on earth, now buoyant on the air.
>
> COWPER.

Gnats deposit their eggs in a kind of slimy matter on the surface of the water, and fasten them to something that may prevent their being washed away, or separated too soon. From these eggs proceed a number of minute worms, which, sinking to the bottom of the water, make for themselves cases or coverings of fine sand or earth, cemented together with a sort of glue, but open at both ends, for them to come out of or retire into as they find occasion. After a time they quit these habitations and the figure of worms; they re-ascend to the top of the water, shelled all over, with a large head and mouth, a couple of black eyes, two horns, several tufts of hairs on different parts of the body, and a tail with a brush of hair at the end of it, which being smeared over with an oily fluid, serves, like a cork, to keep them above water; their heads being sometimes lifted into the air, and sometimes plunged into the water, while the tail slides along the surface. If the oil on the tail begins to dry, they shed from their mouths a new supply upon it, which restores the ability of steering where they please, without being wetted or injured by the water. After living, in this manner, the time appointed by Providence, a stranger change succeeds; for, resigning their eyes, horns, and tail, and casting off their whole skin, there issues forth a race of insects belonging to a different element. The most beautiful and delicate plumage adorns their heads; their limbs are constituted with the finest texture; they have wings curiously fringed and ornamented; their whole bodies are invested scales and hair, and they are actuated with surprising agility: in short, they become gnats, and rise into the atmosphere. And what seems the most wonderful is, that a creature, which but a minute before was an inhabitant of the water, would now be drowned if it were plunged into it.

This little creature is a beautiful object for the microscope; its white heart beating distinctly, and the motion of all its intestines being perfectly visible. The waters indeed every where abound with life, and are an endless subject of employment for the microscope. Rivers, ponds, ditches, and almost every puddle will, by its assistance, present us with living wonders:

The little gnat, in beauties may compare
With all his rival brothers of the air;
Transparent feathers, purple, green, and gold,
His wings, small feet, and gay fringed tail enfold;
Four sharpen'd spears his head with weapons arm,
And his pearled eyes, with liveliest graces charm.
BROWNE.

Mr. Leeuwenhoek, in some papers in the Philosophical Transactions, describes several animalcules found adhering to the roots of the duck-weed. Of these one sort was shaped like bells, with long tails, by which they fastened themselves to the roots of these weeds; and sometimes twenty of them were seen together, gently extending their long tails and bodies, and then, in an instant, contracting them again. Another extraordinary kind appears in a sheath or case, the end of which it fastens to the duck-weed roots. This little creature has seemingly two wheels, with teeth or notches coming from the head, and turning round as it were on an axis. At the least touch it draws the wheel-work into its body, and its body into the sheath. When every thing is quiet, it thrusts itself out again, and the rotation of the wheel-work is renewed.

In the water, or slimy matter found in leaden pipes or gutters, various kinds of animalcules are frequently to be found, and among the rest, multitudes that appear to have a sort of wheel-work, such as we have described. These creatures, when the water dries away, contract their bodies into a globular figure; they become of a reddish colour, and fixt in the dry dirt, which grows as hard as clay: but whenever such a piece of dirt is put in water, in about half an hour's time they open, and by degrees extend their bodies and swim about; from which it has been concluded, that the pores of their skin are closed so perfectly as to prevent all perspiration; by which means they are preserved till rain falls, when their bodies open, life returns, they swim about and take in nourishment:

> Gradual—what numerous kinds descend,
> Evading e'en the microscopic eye!
> Full nature swarms with life: one wond'rous mass
> Of animals, or atoms organized,
> Waiting the vital breath, when parent Heav'n
> Shall bid his spirit blow. The hoary fen,
> In putrid streams, emits the living cloud
> Of pestilence.
>
> THOMSON.

The discoveries made by the microscope should teach us diffidence and modesty. They will, if properly considered, suggest to us this important truth, that our ideas of matter, of magnitude, and minuteness, are merely comparative. They are taken from ourselves, and from the objects that surround us, beyond which, if we endeavour to extend them, they become indistinct and confused.

CHAP. X.

OF POLYPES, WITH DIRECTIONS FOR FINDING, FEEDING, AND PRESERVING THEM.

POLYPES are to be found in all sorts of aquatic plants, upon branches of trees, pieces of board, rotten leaves, stones, and other substances that lie in the water; they are also to be met with upon the bodies of several aquatic animals, as on the water snail; they generally fix themselves to these by the tail, so that it is a good method, when in search of Polypes, to take up many of these substances and put them in a glass of water. If there be any of these minute animals adhering to them, they will be soon seen stretching out their arms, especially if the glass be suffered to be at rest awhile; for the polypes, which contract themselves on being first taken out of the water, will soon extend themselves again when they are at rest.

They are to be sought for in the corners of ditches and ponds, being frequently driven into these with pieces of wood or leaves, to which they have attached themselves: consequently they may in vain be sought for in one period, where at another they may be found in abundance. They are readily perceived in a ditch when the sun shines on the bottom; in winter they are seldom to be met with: about the month of May they begin to appear and to multiply.

They are generally to be found in waters which move gently; for neither a rapid stream nor stagnant waters ever abound with them. As they are always fixed to some substance by their tails, and are very rarely loose in the water, taking up water only can signify but little; a circumstance which has probably been the cause of much disappointment to those who have searched for them.

The *green* polypes are usually about half an inch long when stretched out; those of the second and third sort are between three-quarters of an inch and an inch in length. Heat and cold have the same effect upon these little creatures that they have upon those of a larger size. They are animated and enlivened by the former, whereas the latter renders them languid.

M. Trembley of Geneva, was the first person who discovered these little animals, as he was looking for other insects in the water. He saw some little things which he took for plants; but upon careful examination, he perceived motions in them, and found them contract when touched. It was some time before he could determine whether they were plants or animals; for he saw several young shoots coming out from them, as far as four generations, hanging to one another. At length he saw them eat insects, and even small pieces of raw meat.

He cut one of these creatures to see what would become of it, and in a few days new arms were seen growing out where the others had been cut away.

Since that, both he and other persons have divided them lengthways and breadthways, and every possible way, and always producing the same effect.

Polypes do not swim but crawl, either on the ground or on aquatic plants, pieces of wood, leaves, &c. Their common posture is to fasten their tails to something, and then extend the arms and body into the water; and they make use of their progressive motion to place themselves conveniently for this purpose. Their little arms are so many snares stretched out to catch small creatures in the water; and when any insect happens to touch an arm it is caught, and conveyed to the mouth by the contraction of that arm; but if the creature struggles the other arms assist.

They are very voracious animals: a polype can swallow a worm twice or thrice its own length. They eat more or less in proportion to the heat of the weather; and they increase in size according to what they devour: they will, however, live whole months without food. But the most extraordinary part of M. Trembley's account is this: "If one of them," says he, "be cut in two, the fore part, which contains the head, and mouth, and arms, lengthens itself, creeps, and eats on the same day. The tail part forms a head and mouth at the wounded end, and shoots forth arms more or less speedily as the heat is favourable. If the polype be cut the long way through the head, stomach, and body, each part is half a pipe, with half a head, half a mouth, and some of the arms at one of its ends. The edges of these half pipes gradually round themselves and unite, beginning at the tail end; and the half mouth and half stomach of each becomes complete. A polype has been cut lengthways at seven in the morning, and in eight hours afterwards each part has devoured a worm as long as itself."

When polypes were first discovered it was with difficulty that proper food could be found for their subsistence. It is now well known that the small red worms which are to be met with on the mud banks of the Thames, particularly near the shores, answer the purpose well. They are easily obtained when the tide is out, when they rise in swarms in the mud. If a sufficient quantity be gathered in November, and put into a glass full of water, with three or four inches of earth at the bottom, there will be a supply for the polypes for the whole winter.

River or any soft water agrees with them; but they will not live long in hard water; and the worms with which the polypes are fed should always be cleansed before they are given to them. Polypes are frequently infested with a small species of lice, from which they must be freed to preserve them in health. This may be done by rubbing them, as they adhere to any substance, with a hair pencil. The water also must be frequently changed and kept as free as possible from all impurities.

To observe with accuracy the various habitudes, positions, &c. of the polype, it will be necessary to place some of them in narrow cylindrical glasses, then, by means of the microscope, they may be seen exerting all the actions of life with ease and convenience.

We cannot help observing, as a conclusion to this part of our work, that if the smallest living creatures that have yet been discovered are produced in the waters, in them also are the largest and most monstrous. No bird or beast comes near the size of many kinds of fishes; nor can the elephant itself be brought in comparison with the whale. Let us reflect then how amazing the disparity between such a fish as the whale and a minute animalcule less than a millionth part of a grain of sand! How innumerable must the kinds of creatures be, that form the progressions from one size to the other! and how equally wonderful does the hand of Providence appear, whether it give life and activity to a mountain of matter, or to an indefinitely small atom!

CHAP. XI.

OF THE BLOOD; OF WHAT COMPOSED, HOW TO BE EXAMINED: THE CIRCULATION OF THE BLOOD: IN WHAT OBJECTS BEST SEEN.

THE microscope has been employed for viewing the blood, both with regard to its natural course, and its contexture, and the knowledge derived from these enquiries has been successively applied in the science and practice of medicine. By viewing the blood within the vessels, we may judge of the situation, dimensions, arrangements, and ramifications, of the arteries and veins through which it passes, together with the general state of the fluid. When taken from the vessels we can examine it more minutely, and observe all the alterations that may occur in the mixture, size, form, and quality of the particles composing its more solid or more fluid parts.

Human blood, and the blood of all land animals, is found to consist of round red globules, floating in a transparent water and serum. Each red globule is made up of six smaller and more transparent ones; and each of these again is composed of six globules still more minute and colourless; so that every common red globule is compounded of at least thirty-six smaller ones, though it is probable the division goes on much farther.

As the microscope has informed us of the structure of the blood, which, without its aid, could never have been known, we shall now give some directions for viewing it.

Take, with a soft hair pencil, a small drop of warm blood, immediately from the vein, spread it as thinly as possible on the clearest single isinglass, placed on a slider for the purpose, and apply it to the first or second magnifier: the globules will then be distinctly seen. It may also be examined by taking up a little of it in a very small capillary tube of the thinnest glass, placed before the magnifier.

If a drop of the same blood be diluted with warm water, and applied in either of these ways, some of the larger globules will appear more asunder, and a great many of them will be seen divided into the smaller ones of which they are composed.

If it be mixed with a little warm milk, several red, unbroken globules will be seen distinctly; but those that are again separated into their smaller ones will be confounded with the milk itself.

To see the circulation of the blood, we must make use of such small creatures as, by their transparency, permit us to look within them, and see what passes there; for, in man or other large animals, the skin is so opake that we cannot discern even the fine blood-vessels themselves, and much less the current that runs along them. But there is every reason to believe that the whole animal creation is formed in the same way, and that the circulations in the meanest living creature are carried on through vessels of a like structure as in the noblest.

Indeed, with regard to the circulation of the fluids, the motion of the intestines, the brain, &c. more knowledge may be obtained by inspecting insects and small animals with the microscope, than by the most skilful and curious dissections, or anatomical experiments, on larger subjects. For the skins of some of these little creatures are so transparent, that the order and disposition of the vessels underneath may be plainly observed. In several of them not only is the general course of the blood readily distinguished, but the figure of the globules of which it is composed, and the alterations that they suffer, when they pass out of the larger into the more minute vessels. Many of the vessels are so small that even single globules cannot possibly find a passage through them without being compressed into oval shapes: and yet these vessels are large in comparison of the finest vessels of all, to pass through which the globules must be divided and subdivided into their smallest and most minute component parts.

The wisdom and goodness of Providence are manifest in preventing the blood from coagulating into masses, by the disposition of the vessels through which they run. The arteries, for example, which convey the blood from the heart to the extremities, are in their progress continually diminished, and are divided into smaller branches. At every such division many of the globules of the blood must rush with a considerable force against an angle directly in their way, which motion seems perfectly well adapted to prevent the mass from coagulating. By means of the veins the blood returns from the extremities to the heart; the diameters of these enlarge as the tide rolls along; and the smaller branches are continually uniting and making larger vessels, till at last all their streams fall into one: here, at every conjunction of two branches the currents rush against each other with violence; hence unnatural cohesions are broken or prevented, of which the microscope affords ocular demonstration.

When the vessels are extremely small, it is not always possible to distinguish the veins from the arteries. But the larger arteries are observable by a protrusion of the blood at each contraction of the heart, then a stop, and then a new protrusion, which, with a small degree of attention, may be plainly seen succeeding one another; whereas the current passes through the veins with an equal and unremitting stream.

The transparent membrane between a frog's hind-foot toes is the object most commonly employed for viewing the current and circulation of the blood; and in this, if well expanded, it may be distinctly seen both in the veins and arteries.

The tails or fins of small fishes may be likewise used with advantage to the purpose; they present to view a great number of veins and arteries, with the blood passing different ways through them. Put, for instance, a small eel, well cleaned from its slime, into a glass tube filled with water, and stopping both ends to prevent the water from running out; apply the tail part to the microscope, and the circulation will be readily discovered. It will be as well seen in the tail of a small flounder, and in other fish the skins of which are transparent.

Mr. Leeuwenhoek says, he saw, in the utmost extremity of a very minute fish's tail, in what manner the larger arteries were there divided into the most fine, and, to him, evanescent ones; and that many of the smallest veins, returning from the extremities, met together at last in some larger vein. There appeared also in some vessels a surprising agitation of the blood; and in the larger arteries he could perceive a continual new protrusion, or acceleration of the blood's course received from the heart; but in the smaller arteries the motion seemed equable; and though in the minuest vessels there appeared no colour, yet in the larger vein or artery, though near the tail, the blood was plainly red. In a small part of the tail, the same gentleman counted 34 veins, and as many arteries. The whole fish was not more than half an inch in length, of course the tail must be portionally small; nevertheless, in a part of of that, the circulation of the blood was visible in 34 places, and the current of it in 68 vessels! and yet these vessels were far from being the most minute of all. How inconceivable, then, must be the number of circulations in the human body; of course there can be no need for surprise to behold it issuing forth at every prick of a pin or needle.

CHAP. XII.

OF THE SCALES OF THE HUMAN SKIN; HOW EXAMINED: OF THE PORES OF THE HUMAN BODY; HOW EXAMINED: OF ANIMALCULES FOUND BETWEEN THE TEETH: OF THE ITCH: OF THE STINGS OF INSECTS.

THIS chapter will be devoted to observations on various miscellaneous objects connected with the microscope, in which the wonders of creating Power will be eminently displayed. We shall begin with the *scales* on the *human skin.*

The scarf-skin, or outward covering of the body, is remarkable for its *scales* and *pores*. The former are so minute, that two hundred of them may be covered with a grain of sand, of course they could never be discerned by the naked eye. They are placed as on fishes, three deep; that is, each scale is so far covered by two others, that only a third part of it appears, which, lying over one another, may be the cause why the skin of the body appears white; for about the mouth and lips, where they only just meet, and do not fold over, the blood-vessels are seen through, and the parts look red. The perspirable matter is supposed to issue between these scales, which lie over the pores, and may find vent in an hundred places round the edges of each scale.

A piece of skin taken from between the fingers, from the forehead, neck, arms, or any other soft part of the body which is not hairy, serves best to shew the scales; for where the skin is callous, they are glued as it were together. If they are scraped off with a penknife, put into a drop of clear water, and so applied to the microscope, they will be seen to good advantage.

In order to view the pores cut a slice of the upper skin with a sharp razor as thin as possible; then immediately cut a second slice from the same place, which apply to the microscope, and in a piece not larger than a grain of sand would cover, innumerable *pores* will be perceived, as plainly as little holes pricked in paper by a fine needle may be discerned if it be held up against the sun.

Mr. Leeuwenhoek endeavours to give some slight notion of the incredible number of pores in the human body. He supposes,

poses, on a very moderate calculation, that there are at least one hundred pores in the length of one tenth of an inch; consequently in an inch there will be one thousand, and in a foot there will be twelve thousand; of course, in a surface equal to twelve inches square, there will be one hundred and forty-four millions, and if the superficies of a middle-sized person be reckoned at fourteen feet square, there will be in his skin two thousand and sixteen millions of pores, through which, in health, the perspirable matter is perpetually issuing.

The pores through which we perspire are more particularly remarkable in the hands and feet; for if the hand be well washed with soap, and examined with a tolerably good glass, in the palm, or upon the ends and first joints of the thumb and fingers, innumerable little ridges parallel to each other, of equal bigness and distance, will be found; upon these ridges the pores may, by the naked eye, be perceived lying in rows; but viewed through a good glass, every pore seems like a little fountain, with the perspiratory matter standing in it as clear as rock water; and, if that be wiped away, more will be found to spring up again.

When we consider the multitude of orifices all over the skin, it may be reasonably conjectured that minute animals, as fleas, gnats, &c. do not make new perforations, but rather insinuate their slender instruments into the vessels of the skin, and suck out the blood, or what other humour is their proper aliment.

To warn our young reader of the necessity of cleanliness, we shall introduce a subject or two, which, if not very pleasant to discuss, may lead to effects important to their future health. No animalcules are to be found in the saliva, but great numbers of different kinds may be discovered in the whitish matter sticking between the teeth; if it be picked out with a needle or point of a tooth-pick, and mixed with a little rain water, and applied before the microscope, numbers will be visible. Sometimes, indeed, they are so very numerous, and so very active, that the whole mass appears alive. The largest sort move very swiftly; these are but few in number. The second sort are more numerous, and have different motions.

tions. The third kind are roundish, and so minute that a grain of coarse sand would equal a million of them in bigness; they move so swifty, and in such multitudes, that they seem like swarms of gnats or flies.

Some or all of these three kinds may be found constantly in the matter taken from between the teeth of men, women, and children, especially from between the grinders, even though they wash their teeth with great care. But from the teeth of those who are inattentive to cleanliness, the matter affords another sort of animalcules in the shape of eels. They all die if vinegar be applied to them; hence it has been concluded that a gargle made of vinegar is good for preserving the teeth and gums from injuries that these little creatures might occasion.

The microscope has discovered what would not otherwise have been imagined, that the disorder called the *itch*, which makes such dreadful ravages among those who are inattentive to cleanliness, is owing to little insects under the scarf-skin. These animalcules in shape resemble the tortoise, of a whitish colour, but darker on the back than elsewhere, with long and thick hairs issuing from it. They are very nimble in their motions, having six legs, a sharp head, and two little horns.

We may hence account for the reason why this disorder is catching, since these animacules, by simple touch, easily pass from one person to another, having not only a swift motion, but clinging to every thing they touch, and crawling as well upon the surface of the body as under the outward skin ; and a few being once lodged, they multiply apace by the eggs which they lay. In like manner the infection may be propagated by sheets, towels, handkerchiefs, or gloves, since these animalcules may easily be harboured in such things, and will live some days when separated from the body.

We shall now treat of the *stings* of insects, which are given them by nature to defend themselves from, and to injure their enemies. The *trunk* or *proboscis* which gnats, fleas, and many kind of insects carry in their mouth, though equally sharp with the sting of wasps, bees, &c. is not intended as an intrument of revenge, but for procuring and sucking in their food, and when such creatures bite or sting us, it is from necessity. Squeeze or strike a bee or a wasp, it instantly puts forth its sting: but no provocation can urge a flea or gnat to bite: when disturbed or hurt, they draw in their proboscis, instead of thrusting it out, and never make use of it but when they think themselves perfectly safe and quiet. There is another material difference: a sting injects a venomous liquor into the wound it makes; but a proboscis draws out the blood and humours from it.

As the structure and contrivance of most stings are nearly alike, it will be sufficient to describe that of the bee as discovered by the microscope.

The sting of the bee is a horny sheath or scabbard that includes two bearded darts. This sheath ends in a sharp point, near the extremity of which a slit opens; through this, at the time of stinging, two bearded darts are protruded beyond the end of the sheath; one of which being longer than the other, fixes its beard first, but the other instantly following, they penetrate alternately deeper and deeper; taking hold of the flesh with their hooks, till the whole sting becomes buried in the wound: and then a venomous juice is injected, through the same sheath, from a little bag at the root of the sting, which occasions an acute pain, and a swelling of the part, which continues sometimes for several days.

The artificial convex will reveal
The forms diminutive that each conceal:
Some so minute, that to their fine extreme,
The mite a vast leviathan will seem:
That yet of organs, functions, sense partake,
Equal with animals of largest make,
In curious limbs and clothing they surpass
By far the comeliest of the bulky mass,
A world of beauties! that thro' all their frame,
Creation's grandest miracles proclaim.

BROWNE.

CHAP. XIII.

OF THE HAIR OF ANIMALS—OF THE FARINA OF FLOWERS—HOW TO BE EXAMINED—OF THE SEEDS OF PLANTS, AND OF THE LEAVES.

THE *hairs* of animals are very different in their appearance by the microscope, and can furnish a variety of entertaining observations. They have been discovered to be tubular; that is, composed of a number of extremely minute tubes or pipes. In the hairs of many animals, there are in some spiral lines, and in others transverse ones running from top to bottom. A mouse's hairs are of this sort; they appear, as it were, in joints like the back-bone; they are not smooth, but jagged on the sides, and terminate in the sharpest point imaginable. The hairs taken from a mouse's belly are the least opake, and of course fittest for the microscope.

The hairs of men, horses, sheep, hogs, &c. are composed of long tubular fibres or smaller hairs, encompassed with a rind or bark. A split hair appears like a stick shivered with beating. The roots of hair are of different shapes in different animals; the hair itself is thicker towards the middle than at either end.

The whiskers of a cat, cut transversely, have something in the middle like the pith of elder; and a human hair cut in the same manner shews a variety of vessels in very regular figures. Hairs taken from the head, the eye-brows, the nostrils, the beard, the hand, &c. appear unlike, as well in the roots as in the hairs themselves, and vary as plants do of the same *genus*, but of different *species*.

The *farina*, or mealy powder, found on the little pendant tops of almost every flower, is deserving of the strictest examination. This powder, the colour of which is different in flowers of different kinds, was imagined, by former ages, to be an unnecessary part of the plant; but by means of the microscope we find that all the minute grains of this powder are regular, uniform, and beautiful little bodies, constantly of the same figure and size in plants of the same species; but in different kinds of plants they differ as much as the plants themselves.

It was impossible to observe the order and configuration of the farinæ, without concluding that Providence, which never acts in vain, must intend a nobler use for bodies so regularly formed, than to be dissipated by the winds and lost. This reflection led to farther examination, from which it was evident that this powder is produced and preserved with the utmost care in vessels contrived to open and discharge it when it becomes mature: that there is likewise a seed-vessel in the center of the flower, ready to receive the minute grains of this powder, they either fall of themselves, or are blown out of their little cells. And experience proves, that on this depends entirely the fertility of the seed; for if the farina vessels be cut away before they open and shed their powder, the seed becomes barren and unproductive.

This farina is therefore supposed to be the male seed of plants, and every little grain of its powder may possibly contain in it a minute plant of the species to which it belongs. It is wonderful to observe the various contrivances which nature employs to prevent this powder from being unprofitably dispersed, and to assist its entrance into the seed-vessel prepared for it:

> ——————in an insect or a flower,
> Such microscopic proofs of skill and power,
> As hid from ages past, God now displays,
> To combat Atheists with in modern days.
>
> COWPER.

An inquisitive person will find inexpressible delight in examining and considering the varieties of farinæ discoverable in the vegetable species. In that of the mallow, each little grain appears to be an opake ball, with prickles issuing from it on every side. The sun-flower farina seems composed of flat circular minute bodies, sharply pointed round the edges; the middle part appears transparent, and exhibits some resemblance to the flower from which it proceeds. The powder of the tulip is exactly shaped like the seeds of cucumbers and melons; that of the poppy appears like pearl barley; and that of the lily is not very dissimilar from that of the tulip.

To examine the farina, it must be gathered in the midst of a sun-shiny day, after the dew is completely off: it must not be pressed, but shaken or gently brushed off with a soft hair-pencil upon a piece of clean white paper. A single talc or piece of isinglass being breathed on, and instantly applied to the farina, will take up some portion of it. If too great a quantity be taken, a part may be blown off; it is then to be applied to the microscope; and if the small grains are spread in a regular order, they may be covered cautiously with another talc, which is to be fastened with a brass wire. The glasses or talcs must not press on the farina, because the least pressure would destroy the true figure of the balls.

A collection of the most remarkable farinæ, thus preserved, will afford lasting entertainment to those who take pleasure in pursuits of this kind. To those, into whose hands our little work may fall, a diligent examination is recommended of the little cells that contain the farina, and of the other small parts of flowers. They may begin with the flower of the blind nettle, or even with that of the common mallow, and in these beauties will be discovered that are not easily described. And as every flower has organs adapted for similar uses, though of a different form and structure, here is ample field for investigation, every part of which is capable of leading man to the knowledge of the wonderful works of his Maker.

From the farina the reader might be directed to the seed, the smallest kinds of which are very fit objects for the microscope; such are the seeds of lettuce, thyme, chervil, parsley, and a multitude of others. It would be thought tedious to enumerate the beauties of these; but the powder or seed of the puff-ball may claim a few words; this substance, if crushed when ripe, seems to the naked eye like a smoke or vapour; and when examined by one of the best magnifiers, it appears to be an infinite number of little gloubules of an orange colour, almost transparent; the axis of one of these is not above the fiftieth part of the diameter of a hair; so that a cube whose side was equal to the breadth of a hair, would be equal to an hundred and twenty-five thousand of them.

The *leaves* of trees and plants will also be found deserving of attention from those who are in possession of a good microscope; they are full of innumerable veins and ramifications.

mifications, that convey the perspirable juices to the pores for their discharge. M. Leeuwenhoek reckoned in a single leaf of a species of box more than three hundred thousand pores. The leaves of rue seem full of holes like a honey-comb: all kinds of the plant called St. John's wort appear likewise stuck full of pin-holes; but the microscope shews, that the places where those holes seem to be, are really covered with an exceedingly thin and white membrane. A sage-leaf appears like a rug or shag full of knots tasselled with silver thrums, and embellished with fine round crystal beads or pendants, fastened by little foot-stalks. The underside of the sweet-briar leaf appears diapered with silver.

Leaves of stinging-nettles are thickly set with prickles, that penetrate the skin when touched, and occassion pain, heat, and swelling. The microscope shews that these prickles are formed and act in the same manner as the stings of living animals, every one of them being a rigid hollow body, terminating in a very acute white point, with an opening near its end. At the bottom of this cavity lies a minute vessel, containing a limpid liquor, which, upon the smallest touch of the prickle, is squirted through the little out-let; and if it enters the skin, produces those painful sensations, which almost every person has experienced. Hence it comes to pass, that when the leaves of nettles are considerably dried, they sting but little; whereas, such as are green and juicy produce violent pain and inflammation.

CHAP. XIV.

THE WORKS OF ART AND NATURE COMPARED TOGETHER AND CONSIDERED.

UPON examining the edge of a very keen razor with a microscope, it will appear as broad as the back of a thick knife; rough, uneven, full of notches and furrows, and so far from any thing like sharpness, that an instrument as blunt as this seemed to be, would not serve even to cleave wood. An exceedingly small needle resembles, as we have already seen, a rough iron bar, rather than a fine, polished, and slender instrument going off at a point.

But the sting of a bee, seen through the same instrument, exhibits every where a polish most amazingly beautiful, without the least flaw, blemish, or inequality, and it ends in a point too fine to be discerned.

A small piece of exceedingly fine lawn appears, through a microscope, from the large distances and holes between its threads, somewhat like a hurdle or lattice, and the threads themselves seem coarser than the yarn with which ropes are made for anchors.

But if a silk-worm's web were to be examined, it would appear perfectly smooth and shining, every where equal, and as much finer than any thread, as the smallest twine is finer than the thickest cable. A pod of this silk has been wound off which measured more than eighteen hundred yards, and which when weighed was found no heavier than two grains and a half. Yet this exquisite fineness is not to be compared to the web of a small spider.

The smallest dot, tittle, or point that can be made with a pen, appears, when viewed by the microscope, a vast irregular spot, rough, jagged, and uneven all about its edges. The finest writing, such as the Lord's Prayer in the compass of a silver penny, when examined by a microscope, is shapeless, uncouth, and barbarous, as if written in the coarsest characters. But the little specks on the wings or bodies of moths, beetles, flies, and other insects, are found, when magnified, to be most accurately circular, and all the other lines and marks about them appear regularly and finely drawn to the greatest degree of exactness.

A golden chain has been made, consisting of three hundred links, not more than one inch in length, fastened to and pulled away by a flea. And Mr. Baker, whose work on the microscope has been long and highly celebrated, says, he saw and examined a chaise, made by Mr. Boverick, having four wheels, with all the proper apparatus belonging to them, turning regularly on their axis; together with a man sitting in the chaise, all formed of ivory, and drawn along by a flea without seeming difficulty. The same artist made a brass chain consisting of two hundred links, with a hook at one end, and a padlock and key at the other, all of which did not weigh a third part of a grain.

Oswald Neelinger, a German, made a cup of a pepper-corn, which held twelve hundred other little cups, all turned in ivory, each of them being gilt on the edges, and standing on a foot. And Mr. Baker says, he saw a quadrille table, with a drawer in it, an eating table, a side-board table, a looking-glass, twelve chairs with skeleton-backs, two dozen of plates, six dishes, a dozen knives and as many forks, twelve spoons, two salts, a frame and castors, together with a gentleman, lady, and footman, all contained in a cherry-stone, and not filling much more than the half of it.

These are some of the nicest, most curious, and surprising works of art; but if these be examined with a good microscope, it must be confessed that the utmost art is only a concealment of deformity, an imposition on the want of sight; and the admiration which they excite arises from our ignorance of what they really are.

A microscope will prove the most boasted performances of art to be as ill-shaped, rugged, and uneven, as if they were hewn with an axe, or struck out with a mallet and chissel. It will shew the inequality and imperfection of every part. The finest miniature paintings appear before this instrument as mere daubings, plastered on with a trowel, entirely void of beauty, either in the drawing or the colouring. The most even and beautiful varnishes and polishings will be found to be mere roughness, full of gaps and flaws.

Thus sink the *works of art*, when by means of good glasses we see what they really are. But the nearer we examine the *works of* GOD, even in the least of his productions, the more sensible shall we be of the wisdom and power of our great Creator. Apply the microscope to whatever of his works we will, nothing is to be found but beauty and perfection. If we examine the numberless species of insects that swim, creep, or fly around us, what proportion, exactness, uniformity, and symmetry shall we perceive in all their organs! what a profusion of colouring! azure, green, and vermilion, gold, silver, pearls, rubies, and diamonds; fringe and embroidery on their bodies, wings, heads, and every other part! how high the finishing! how inimitable the polish we every where behold!

Their wings all glorious to behold,
Bedeck'd with azure, jet and gold,
Wide they display: the spangled dew
Reflects their eyes and various hues.

GAY.

If we go farther and examine the animalcules, many of which the unassisted human eye could never discern, in them we discover the same organs of body, multiplicity of parts, variety of motions, diversity of figures, and particular ways of living, as in the larger animals. How amazingly curious must the internal structure of these creatures be! the heart, the stomach, the entrails, and the brain! How minute and fine the bones, joints, muscles, and tendons! How exquisitely delicate, beyond all conception, are the arteries, veins, and nerves! what multitudes of vessels and circulations must be contained within this narrow compass! Yet all have sufficient room to perform the different offices, and neither impede nor interfere with one another:

Fluids, in drops, minutely swell,
These subtile beings each contains;
In the small sanguine globes they dwell,
Roll from the heart, and trace the veins.
Through every tender tube they rove,
In finer spirits strike the brain,
Wind quick thro' ev'ry fibrous grove,
And seek, thro' pores, the heart again.

SAVAGE.

The same order, regularity, and beauty,

will appear among *vegetables* if properly examined. Every stalk, bud, flower, or seed, displays a figure, a proportion, a harmony beyond the reach of human art. There is not a weed nor a moss, the leaf of which does not exhibit a multiplicity of vessels and pores disposed most curiously for the conveyance of juices to support and nourish it, and which is not adorned with innumerable graces to embellish it.

The most perfect works of art betray a meanness, a poverty, an inability in the workman; but the works of nature plainly prove, that the hand which formed them was absolute master of the materials upon which it acted, and had tools exactly adapted to its design. Every hair, feather, or scale, even of the meanest insect, appears rounded, polished, and finished to the highest pitch, and shews the abundant riches, munificence, and skill of its Maker.

> What atom forms of insect life appear!
> And who can follow Nature's pencil here?
> Their wings with azure, green, and purple gloss'd,
> Studded with coloured eyes, with gems emboss'd,
> Inlaid with pearl, and mark'd with various stains
> Of lively crimson thro' their dusky veins
>
> BARBAULD.

After all, what we know at present, even of things the most near and familiar to us, is so little in comparison of what we know not, that there remains a boundless scope for our inquiries; and every step we take serves to enlarge our capacities, and to give us still more noble and just ideas of the power, the wisdom, and the goodness of the Deity.

FINIS.

Directions to the Binder.

1 Frontispiece (A Louse as seen through a Microscope) to face the Title ✓
2 The Microscope — — — page 10 ✓
3 The Mites in Cheese magnified — 24 ✓
4 A Flea, as seen through a Microscope — 28 ✓
5 The Blue-bottle Fly in a Microscope magnified 57 ✓

TECHNICAL TERMS

Made use of in this Work.

ANIMACULES---are the smallest living creatures yet known, and are found in fluids, whereof many kinds have been discovered by the microscope.

CONCAVE---a glass being hollow in the middle, or thicker at the edges than at the centre, is called concave.

CONVEX---a glass having a round or circular side; that is, being thicker in the middle than at the edges.

CUTICLE---the outer skin of the human body, called also the scarf-skin. It is that part of the skin which is raised in blisters, and is a thin white elastic layer under which is a much thicker layer, composed of a great many fibres, closely interwoven, and disposed in different directions; this is called the *cutis*, or true skin.

FOCUS---the point where the rays of light meet, which is shorter or longer according to the convexity or roundness of the glass; a little convexity throwing it to a considerable distance; but when the glass is more round and thick, the focus is very near.

LENS---any optical glass not very thick, which either collects the rays of light into a point in their passage through it, or disperses them apart. If convex on both sides it is called a *convex lens;* but if one side be flat a *plano-convex;* if concave on both sides, it is termed a *concave-lens;* if flat on one side a *plano-concave;* if convex on one side and concave on the other, a *conveno-concave* or *concavo-convex.*

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